From:	Sophie Dwyer
Sent:	Friday, 28 October 2016 4:44 PM
To:	Rhiannon Boden; Jeannette Young; SDLO
Cc:	Peter Gillies; Peter Boland; Penny Hutchinson
Subject:	RE: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

Dear Rhannon and Jeannette
The focus of the session is on the ecological risk assessment, which is more to do with impact of contamination on the general environment – animals and plants. It has little contribution to make regarding human health. We did not provide input into the ecological risk assessment.

The previous walk in session addressed the human health risk assessment which was released last month which we attended. Also, the Commonwealth Department of Health went there last week to discuss the blood testing program, and the national guidance developed by Enhealth.

As the walk in session has little relevance to health, and health was the focus of the meeting last week, it is reasonable that there is no health participation except to support people if required.
Regards
Sophie

Queensland Government
Sophie Dwyer PSM
Executive Director
Health Protection Branch, **Department of Health**
p: 07 3328 9266 | **m:** [redacted]
a: 15 Butterfield Street, Herston, Qld, 4006
w: Queensland Health | **e:** Sophie.dwyer@health.qld.gov.au

Queensland's health vision | *By 2026 Queenslanders will be among the healthiest people in the world.*

Queensland Health acknowledges the Traditional Owners of the land, and pays respect to Elders past, present and future.

From: Rhiannon Boden
Sent: Thursday, 27 October 2016 10:30 AM
To: Jeannette Young; SDLO; Sophie Dwyer
Cc: Peter Gillies; Peter Boland; Penny Hutchinson
Subject: FW: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

Hello All,

We have received the attached correspondence from the Department of Defence regarding the Defence's next planned Community Consultation session on 9 November to discuss the findings of the Preliminary Ecological Risk Assessment (ERA) Report.

Evan from the PFAS Coordination Unit, Department of Health has advised that the Federal Department of Health are not planning on sending any representatives to this session.

We have not seen a copy of the Preliminary ERA report so it's unclear what if any representation is required from us at this event other than to continue to advise the community that we can provide mental health and counselling services (for which there has been very limited uptake). Has the Department received, or is aware of the content of, this report from Defence? Appreciate your advice on whether the Department will be sending any representatives to this event, especially relating to specialist advice on the environmental health response? Thanks.

Regards,
Rhiannon

Rhiannon Boden
A/Director Executive Services | Office of the Chief Executive
Darling Downs Hospital and Health Service

Baillie Henderson Hospital
Jofre
Cnr Tor and Hogg Streets
Toowoomba QLD 4350

P: 07 4699 8402 | **F:** 07 4699 8400
M: [redacted]
E: Rhiannon.Boden@health.qld.gov.au
Or DDHHS_Board@health.qld.gov.au
Web: http://www.health.qld.gov.au/darlingdowns/

From: Harvey, Renee MS [mailto:renee.harvey@defence.gov.au]
Sent: Wednesday, 26 October 2016 11:24 PM
To: Rhiannon Boden; 'virginia.berry@premiers.qld.gov.au'
Cc: Darrow, Seima MRS
Subject: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

UNCLASSIFIED

Hi Virginia and Rhiannon,

Please find attached an invitation to a Defence facilitated community walk-in session to be held in Oakey on 9 November.

We would appreciate your assistance facilitating RSVPs from relevant departmental representatives.

Please let me know if you need any additional information.

Many thanks
Renee

Renee Harvey
Contractor to Defence
Environmental Remediation Programs
Department of Defence
M: [redacted]

BP3-2-B021
Brindabella Circuit
Brindabella Business Park
PO Box 7925 Canberra BC 2610

Australian Government
Department of Defence
Estate and Infrastructure Group

Seima Darrow
Director
Communications and Engagement
PFAS Investigation and Management Branch
Department of Defence
Brindabella Circuit, Brindabella Business Park
PO Box 7925 Canberra BC 2610
☎: (02) 6266 8423
💻: seima.darrow@defence.gov.au

26 October 2016

Dr Virginia Berry
Environment Policy
Queensland Department of the Premier and Cabinet
Executive Building
Level 14, 100 George Street
Brisbane QLD 4000

Virginia.Berry@premiers.qld.gov.au

Dear Dr Berry

Re: Oakey Environmental Investigation Community Walk-In Sessions – 9 November 2016

I am writing to request your assistance in coordinating representation from Queensland Government agencies at the Community Walk-In Sessions being held by the Department of Defence in Oakey on 9 November 2016.

Two Community Walk-In Sessions will be conducted on the day and will provide local residents and business owners with the results of the Preliminary Ecological Risk Assessment (ERA) and an update on the environmental investigation into per- and poly-fluoroalkyl substances (PFAS) at the Army Aviation Centre Oakey. The Preliminary ERA assesses the potential for adverse effects to occur in wildlife as a result of contact with soil, sediment or surface water containing PFAS in the Investigation Area and the effects to wildlife as a result of eating plants or animals that have been exposed to PFAS.

The sessions will provide local residents and business owners with an opportunity to gain information about the project and to ask questions, one-on-one with the project team. Details for this event are as follows:

Date: Wednesday 9 November 2016

Time: Morning session: 10am-1pm
Afternoon session: 4pm-7pm

Venue: Oakey Cultural Centre, Corner McDonald and Campbell Streets, Oakey Qld 4401

The Department of Defence will be providing 15 minute presentations at regular intervals throughout the day. Presentations will be held at the following times:

Morning Session Presentations:	Afternoon Session Presentations:
10:30am – Defence Presentation 12:00pm – Defence Presentation	4:30pm – Defence Presentation 6:00pm – Defence Presentation

A pre brief will be provided for representatives attending this event. This is scheduled for 9:00-9:30am and 3:00-3:30pm at Oakey Cultural Centre, Corner McDonald and Campbell Streets.

I anticipate representation from the Departments of Health, Environment and Heritage Protection, and Agriculture and Fisheries, and Darling Downs Hospital and Health Service, and Natural Resources and Mines.

It would be extremely beneficial if Departmental representatives could attend both sessions on 9 November, including both pre-briefs. This will ensure a coordinated approach to the delivery of sessions and follow-up discussions.

Grateful if Departmental representatives participate in the community walk-in sessions and provide useful information relevant to their Department's activities, including handouts, and answer any questions the community may have at these sessions.

My point of contact is Renee Harvey, the Defence Project Manager for AACO. Renee can be contacted on [redacted] or renee.harvey@defence.gov.au. Grateful if you can please RSVP to Renee by 5pm, Wednesday 2 November 2016. Table layouts will be determined upon staff availability.

If you have any enquiries regarding this matter please do not hesitate to contact either Renee or myself.

Yours sincerely

Seima Darrow
Director
Communications and Engagement
PFAS Environmental Management Program

CC:
Rhiannon Boden
A/Director Executive Services | Office of the Chief Executive
Darling Downs Hospital and Health Service
Rhiannon.Boden@health.qld.gov.au

Attachment A:
Important Information
AACO, Preliminary Ecological Risk Assessment Community Information Events

Environmental Site Assessment Report		
Session	**Purpose**	**Details**
Community Walk-In Sessions Wednesday 9 November 2016	These sessions provide local residents and business owners with an opportunity to ask questions of Defence and Departmental representatives. It is anticipated that Departmental representatives will be active participants during the community walk-in sessions. Defence proposes Departmental representatives provide useful information relevant to their Department's activities, including handouts, and answer any questions the community may have at the community walk-in sessions. At these sessions, individual desks will be set up for key discussion topics. Departmental representatives will be allocated to relevant desks to answer related questions from the community.	**AM Session** **Date:** Wednesday 9 November **Pre-brief:** 9:00am – 9:30am **Session time:** 10:00am – 1:00pm **Location:** Oakey Cultural Centre, Corner McDonald and Campbell Streets Oakey Qld 4401 **PM Session** **Date:** Wednesday 9 November **Pre-brief:** 3:00pm – 3:30pm **Session time:** 4:00pm – 7:00pm **Location:** Oakey Cultural Centre, Corner McDonald and Campbell Streets Oakey Qld 4401
Proposed attendees	An initial list of Departmental representatives (depending on availability) is provided. Based on attendees at the walk in session in July and September 2016, and recent interactions with Departmental representatives during completion of the environmental investigations at Oakey. **Note that only 2 representatives from each department are required.**	• DEHP, Chris Hill • DEHP, Andrew Connor • DEHP, Tony Bradshaw • DEHP, Dave Cook • DNRM, Paul Sanders • DNRM, Jason Chavasse • DNRM, Adrian McKay • DNRM, Oren Farrington • Darling Downs Hospital and Health Service. Dr Penny Hutchinson • Health, Sophie Dwyer • Health, Suzanne Huxley • Health, Judith Vandenbrink • Health, Janet Cumming • DAF, Veronica Slizankiewicz • DAF, Elton Miller • DAF, Ross Savage • DAF, Richard Routley • DAF, Richard Watts • DAF, Peter Kind
RSVP	**Renee Harvey** Mobile: [redacted] Email: Renee.Harvey@Defence.gov.au **Wednesday 2 November 2016,** to facilitate preparation and details of table layouts for the walk-in sessions	

Attachment B:
Detailed sequence of events and proposed table layout
AACO, Preliminary Ecological Risk Assessment Community Information Event

Walk-In Sessions: 10am – 1pm and 4:00pm – 7pm, 9 November 2016, Oakey Cultural Centre

Information Tables:

- The following topic specific information tables will be provided at the Preliminary ERA walk-in sessions. It is proposed that QLD representatives, Lead Consultant staff, Defence representatives and AACO Base staff will staff the topic specific information tables as follows:

Table	Proposed Personnel
ERA	AECOM and Defence project staff **DAF representative (TBC)** **DEHP representative (TBC)**
HHRA	AECOM and Defence project staff **QLD Health representative (TBC)**
Environmental Site Assessment and previous investigation staged	AECOM project staff **DNRM/DSITI representative (TBC)** **DEHP representative (TBC)**
Public Health	Defence senior physician **QLD Health representative (TBC)** **Darling Downs Public Health Unit representative (TBC)**
Water Assistance	Defence project staff **Toowoomba Regional Council representative (TBC)**
Long-term Management Options	Defence and AECOM project staff
Department of Human Services	Department of Human Services

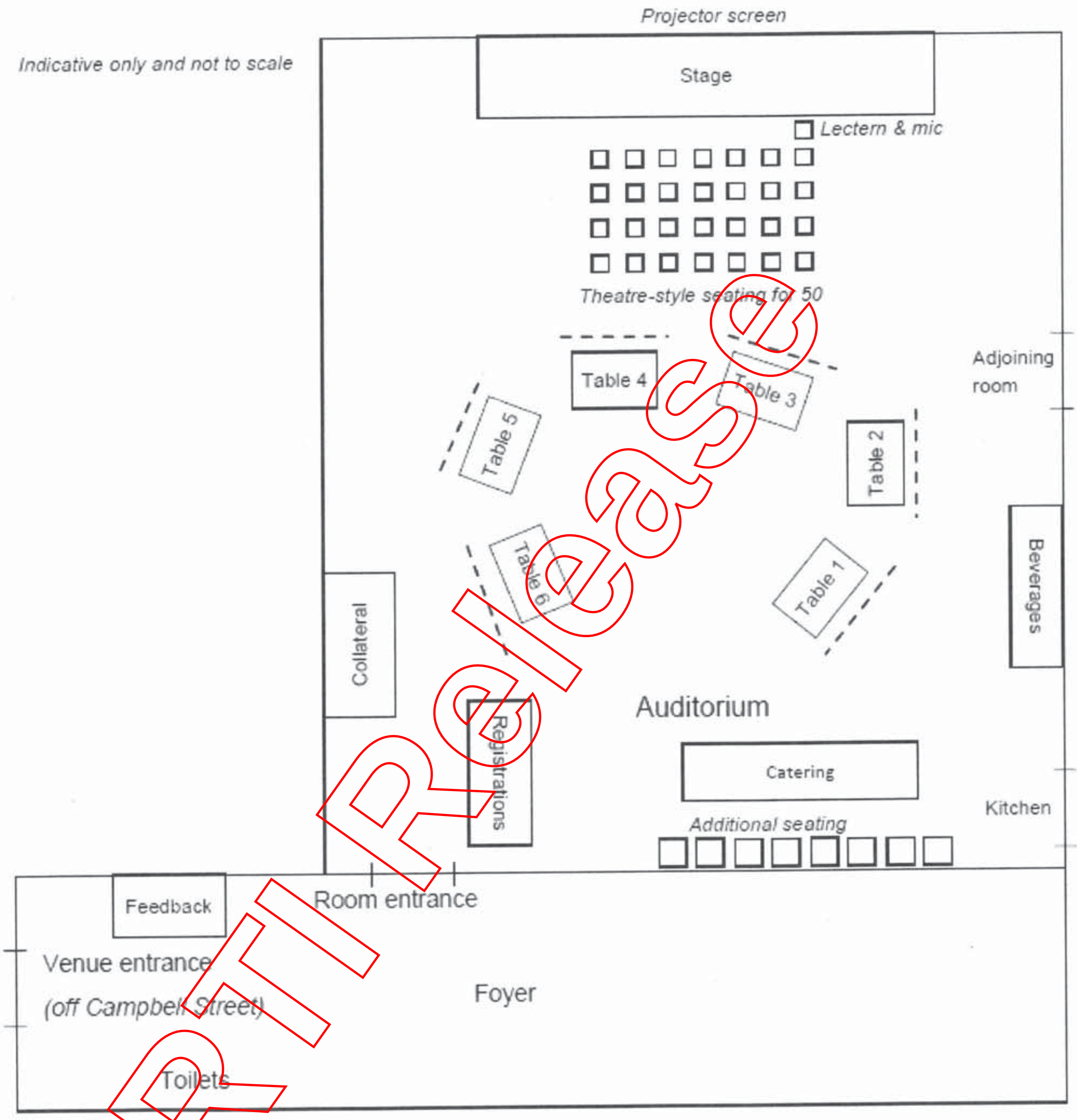
- Each Information Table will have an associated Display Board (e.g Room Divider/Backing Boards/Pin board or Wall) either next to or behind the table. Display Board will contain:
  - a laminated A3 poster with the individual Table name
  - any relevant information for that table. The Lead Consultant is to provide copies of all handouts.

Registration table: Staffed by Lead Consultant. Staff to assist in registering attendees and providing name tags. Information provided at this table to include as a minimum:

- Registration cards and box
- Name tags
- Feedback forms

Kids Corner: Table to contain paper and colouring in pencils at a minimum.

Fig 1: Proposed floor plan for Walk-in Session



Preliminary ERA Walk-in Session Tables:

1) ERA
2) HHRA
3) Environmental Site Assessment and previous investigations
4) Public Health
5) Water Supply
6) Long-term Management Options
7) Department of Human Services

Myra Thompson

From: Sophie Dwyer
Sent: Wednesday, 2 November 2016 3:07 PM
To: Rhiannon Boden; Jeannette Young; SDLO
Cc: Peter Gillies
Subject: RE: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

Many thanks Rhiannon

Queensland Government

Sophie Dwyer PSM
Executive Director
Health Protection Branch, **Department of Health**
p: 07 3328 9266 | **m:** [redacted]
a: 15 Butterfield Street, Herston, Qld, 4006
w: Queensland Health | **e:** Sophie.dwyer@health.qld.gov.au
f in 🐦 ▶

Queensland's health vision | *By 2026 Queenslanders will be among the healthiest people in the world.*

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From: Rhiannon Boden
Sent: Monday, 31 October 2016 10:06 AM
To: Sophie Dwyer; Jeannette Young; SDLO
Cc: Peter Gillies
Subject: RE: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

Thanks Sophie.

Defence has advised that the ERA was issued to the Qld IDC for review and comment a few weeks ago and comments on it were received from Natural Resources and Mines, Agriculture and Fisheries and Environment and Heritage Protection. They have also advised that they intend to issue the ERA report publicly prior to the community session. As you mention, the HHRA continues to be the more relevant report.

The DDHHS's Executive Director Mental Health and Director Aged Care have indicated that they will be attending the sessions to provide advice on the support that the DDHHS can continue to provide to the community.

Regards,
Rhiannon

Rhiannon Boden
A/Director Executive Services | Office of the Chief Executive
Darling Downs Hospital and Health Service

Baillie Henderson Hospital
Jofre
Cnr Tor and Hogg Streets
Toowoomba QLD 4350

P: 07 4699 8402 | **F:** 07 4699 8400
M: [redacted]
E: Rhiannon.Boden@health.qld.gov.au
Or DDHHS_Board@health.qld.gov.au
Web: http://www.health.qld.gov.au/darlingdowns/

From: Sophie Dwyer
Sent: Friday, 28 October 2016 4:44 PM
To: Rhiannon Boden; Jeannette Young; SDLO
Cc: Peter Gillies; Peter Boland; Penny Hutchinson
Subject: RE: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

Dear Rhannon and Jeannette
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Regards
Sophie

Queensland
Government

Sophie Dwyer PSM
Executive Director
Health Protection Branch, **Department of Health**
p: 07 3328 9266 | **m:** [redacted]
a: 15 Butterfield Street, Herston, Qld, 4006
w: Queensland Health | **e:** Sophie.dwyer@health.qld.gov.au

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From: Rhiannon Boden
Sent: Thursday, 27 October 2016 10:30 AM
To: Jeannette Young; SDLO; Sophie Dwyer
Cc: Peter Gillies; Peter Boland; Penny Hutchinson
Subject: FW: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

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Regards,
Rhiannon

Rhiannon Boden
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Darling Downs Hospital and Health Service

Baillie Henderson Hospital
Jofre
Cnr Tor and Hogg Streets
Toowoomba QLD 4350

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M: [redacted]
E: Rhiannon.Boden@health.qld.gov.au
Or DDHHS_Board@health.qld.gov.au
Web: http://www.health.qld.gov.au/darlingdowns/

From: Harvey, Renee MS [mailto:renee.harvey@defence.gov.au]
Sent: Wednesday, 26 October 2016 11:24 PM
To: Rhiannon Boden; 'virginia.berry@premiers.qld.gov.au'
Cc: Darrow, Seima MRS
Subject: Defence Community walk-in session | Oakey | 9 November [SEC=UNCLASSIFIED]

UNCLASSIFIED

Hi Virginia and Rhiannon,

Please find attached an invitation to a Defence facilitated community walk-in session to be held in Oakey on 9 November.

We would appreciate your assistance facilitating RSVPs from relevant departmental representatives.

Please let me know if you need any additional information.

Many thanks
Renee

Renee Harvey
Contractor to Defence
Environmental Remediation Programs
Department of Defence
M:[redacted]

BP3-2-B021
Brindabella Circuit
Brindabella Business Park
PO Box 7925 Canberra BC 2610

From:	Sophie Dwyer
Sent:	Wednesday, 9 November 2016 4:59 PM
To:	Penny Hutchinson
Cc:	Peter Boland
Subject:	Defence Liaison officers
Attachments:	Government Liaison Officers_Oakey_Oct 2016

FYI
Regards
Sophie

Australian Government
Department of Defence

Government Liaison Officers – Points of Contact for the Community
Army Aviation Centre Oakey PFAS Environmental Investigation

The Australian Government has established a dedicated senior liaison officer from the Department of Defence (Defence), a dedicated community liaison officer from Defence and a dedicated community liaison officer from the Australian Government Department of Human Services (Human Services) at Oakey. These appointments improve engagement and access to whole of Government support services for residents in communities impacted by per- and poly-fluoroalkyl substances (PFAS) environmental investigations. Liaison officers are responsible for engaging with the community, local agencies and government representatives to work through the community issues associated with PFAS detections around Army Aviation Centre Oakey.

Mark O'Connell has been engaged as the Senior Defence Liaison Officer, Ray Clarke has been engaged as Community Liaison Officer from Defence and Sue Smith has been engaged as the Community Liaison Officer from Human Services. Mark, Sue and Ray will work to ensure the community has easy access to relevant information and social services managed by the key Australian Government departments coordinating the response to PFAS detections in the Oakey area.

Mark, Sue and Ray will engage with community stakeholders and individuals to: understand the issues most important to the community; and effectively link community members and their families impacted by the presence of PFAS to appropriate government and non-government support.

To aid in access, Sue and Ray will be available Thursdays from 10.00am to 4.00pm at the Oakey Library located at 62 Campbell Street, Oakey. Community members are welcome to drop in on Thursdays to discuss any issues, however it is recommended that to secure a preferred time, community members should ring prior to arrange a booking. Please call Sue weekdays on 07 4577 7102 during business hours to make an appointment.

CONTACT DETAILS

General Enquiries: For enquiries related to residential sampling for PFAS, water delivery and reimbursement of costs please contact the Defence Hotline on 1800 136 129 or email defence.oakey.anz@aecom.com

Government Liaison Officer Enquiries:

Department of Defence	Department of Human Services
Senior Defence Liaison Officer Mark O'Connell P: (07) 45779205 E: mailto:mark.oconnell2@defence.gov.au	Community Liaison Officer Sue Smith P: (07) 45777102 E: sue.smith@humanservices.gov.au

Myra Thompson

From: HILL Chris <Chris.Hill@ehp.qld.gov.au>
Sent: Wednesday, 25 November 2015 11:47 AM
To: Louise Mahoney; Christine Castley; CHO ESO; Jeannette Young; ROUTLEY Richard; LETTS Malcolm; CONNOR Andrew; SANDERS Paul; Sophie Dwyer; Penny Hutchinson
Cc: SAVAGE Ross; SLIZANKIEWICZ Veronica; Greg Jackson; Sharlene Larsen
Subject: Defence visit to Oakey 4/12/15
Attachments: 20151125114505326.pdf

Hi All

FYI. Apparently defence are visiting Oakey next week for some community engagement.

Regards Chris

Queensland
Government

Chris Hill
Director
Industry and Development Assessment | Environmental Services and Regulation
Department of Environment and Heritage Protection

P 07 4699 4360
173 Hume St, Toowoomba, QLD 4350
PO Box 731, Toowoomba, QLD 4350

Tainted water: Army to hold public forum

Andrew Backhouse
andrew.backhouse@apn.com.au

TOP BRASS from the Defence Department and the Member for Groom Ian Macfarlane will front the public in Oakey over the issue of groundwater contamination next week.

The Assistant Minister for Defence, Darren Chester, will join Mr Macfarlane to provide an update to the Oakey community on the issue, which is linked to the Army Aviation Centre.

The Department of Defence undertook an environmental audit of the area around the base in 2010, five years after it ceased using perfluoirnated chemicals in fire-fighting foams in its training exercises and discovered perfluorooctane sulfonate and perfluorooctanoic acid in the groundwater beneath its base.

Contamination from aqueous film forming foam containing the chemicals PFOS and PFOA was detected in the groundwater near the base in 2013.

Mr Chester and Mr Macfarlane will be joined by Defence Department representatives to provide an update on the issue and to answer any questions.

Since 2013, Defence has provided safe drinking water to people who had been relying on bore water for drinking.

There are concerns that people who are highly exposed to PFOS may become immunocompromised.

PFOA is a carcinogen, a liver toxicant, a developmental toxicant, and an immune system toxicant.

It also exerts hormonal effects including alteration of thyroid hormone levels.

Shine Lawyers is investigating a potential legal action on behalf of landholders affected by groundwater contamination.

"I encourage members of the community who have questions to attend the public forum where they will be able to ask questions directly," Mr Macfarlane said.

Mr Chester and officials will provide the latest information on the issue at the public forum.

The meeting will take place at Oakey RSL, 76 Campbell Street, Oakey from 8am until 10am on Friday, December 4.

Myra Thompson

From: SANDERS Paul <Paul.Sanders@dnrm.qld.gov.au>
Sent: Thursday, 3 December 2015 2:43 PM
To: HILL Chris; Louise Mahoney; Christine Castley; Jeannette Young; ROUTLEY Richard; LETTS Malcolm; CONNOR Andrew; Sophie Dwyer; Penny Hutchinson
Subject: RE: Defence visit to Oakey 4/12/15

Hi all,
Is anyone going to this? I'm looking at whether I send someone, or whether I go myself.

Thanks
Paul

Paul Sanders
Regional Manager

Water Services
South Region
Department of Natural Resources and Mines
Telephone: 07 3330 4465 **Facsimile:** 07 3406 2581 **Mobile:** 0407 021 344
Email: paul.sanders@dnrm.qld.gov.au
Landcentre
Cnr Main and Vulture Streets, Woolloongabba Q
GPO Box 2771, Brisbane Qld 4000

From: HILL Chris
Sent: Wednesday, 25 November 2015 11:47 AM
To: Louise Mahoney; Christine Castley; CHO ESO; Jeannette Young (Queensland Heath); ROUTLEY Richard; LETTS Malcolm; CONNOR Andrew; SANDERS Paul; Sophie Dwyer; Penny Hutchinson
Cc: SAVAGE Ross; SLIZANKIEWICZ Veronica; Greg Jackson; Sharlene Larsen
Subject: Defence visit to Oakey 4/12/15

Hi All

FYI. Apparently defence are visiting Oakey next week for some community engagement.

Regards Chris

Chris Hill
Director
Industry and Development Assessment | Environmental Services and Regulation
Department of Environment and Heritage Protection

P 07 4699 4360
173 Hume St, Toowoomba, QLD 4350
PO Box 731, Toowoomba, QLD 4350

Queensland
Government

____

Suzanne Huxley

From: BRADSHAW Tony <Tony.Bradshaw@ehp.qld.gov.au>
Sent: Wednesday, 31 August 2016 2:21 PM
To: Virginia Berry; Suzanne Huxley; CONNOR Andrew; SANDERS Paul
Cc: VENTURA Simone; COOK David
Subject: RE: DRAFT- Queensland Government response to Defence investigation and identification of next steps - Oakey
Attachments: Draft Oakey Letter + TB EHP.docx

Hi Virginia,

here are a couple of last minute suggestions,

cheers Tony

Tony Bradshaw
Technical Specialist
Technical Support and Community Response Regulatory Capability and Customer Service Department of Environment and Heritage Protection
----
P 07 3330 5704
Level 9, 400 George St, Brisbane QLD 4000 GPO Box 2454, Brisbane QLD 4001

Email tony.bradshaw@ehp.qld.gov.au
Website www.ehp.qld.gov.au

Please consider the environment before printing this email

-----Original Message-----
From: Virginia Berry [mailto:Virginia.Berry@premiers.qld.gov.au]
Sent: Wednesday, 31 August 2016 1:05 PM
To: Suzanne Huxley; CONNOR Andrew; SANDERS Paul; BRADSHAW Tony
Subject: DRAFT- Queensland Government response to Defence investigation and identification of next steps - Oakey

Here's the final draft for any last minute changes. All agencies have now provided feedback. Adrian is also about to read it.

VB

Queensland Government response: Army Aviation Centre Oakey – Department of Defence environmental investigation and identification of next steps

Introduction and overview

The following information is prepared in response to the request of the Department of Defence (Defence) of 19 July 2016 that the Queensland Government identify the key items relevant departments would prefer to see included in any additional scope of work in relation to the Army Aviation Centre at Oakey (AACO).

The Queensland Government acknowledges that fire-fighting foam containing per- and poly-fluorinated alkyl substances (PFASs) was used in fire-fighting and fire-fighting training on the AACO. The Australian Government, through the Department of Defence, has responsibility for the AACO and for any impacts on the surrounding residents and environment caused by operations at the facility.

The Queensland Government continues to work with Defence to ensure Defence's obligations are properly met. Importantly, the Queensland Government wants to make sure that Oakey residents have access to up to date information about PFASs and any remediation action that may be required to protect the community. Queensland continues to urge Defence to respond to community concerns and to accept its obligations to ensure that Oakey residents and businesses are protected. The work of Defence to date is acknowledged.

To facilitate communication between the Queensland Government, Defence and the Oakey community, the Department of the Premier and Cabinet chairs an Inter-departmental Committee (IDC) consisting of senior officials from relevant government agencies. This committee coordinates the exchange of information with Defence, monitors progress with investigation work, and provides support for Defence's Oakey public information sessions.

It is the preference of the IDC that Defence develop a management plan to guide further work on or around the AACO (and on any other defence facilities in Queensland where PFAS contamination is present). Such a management plan should consist of, but not be limited to, four primary objectives:

1. minimise further exposure so that PFAS levels in the community return to background levels
2. manage community concerns regarding declining land values, reduced amenity and historical exposure
3. remediate existing contamination
4. prevent future contamination including use of contaminated ground water and newer fire-fighting foams.

The primary issues to be considered by Defence are detailed under each objective (below). (Note that priority rankings are assigned, as requested, for technical feedback).

The information provided is not intended as an exhaustive list of gaps in the AACO investigation. It is it not intended to limit future investigations on or around the AACO, nor should it delay the preparation and release of any current AACO investigations. The following is offered to stimulate ongoing consultation between Defence and the Queensland Government (through the IDC) on the scope of work for further investigations.

Defence's AACO investigation has three components – Environment Site Assessment (ESA); Human Health Risk Assessment (HHRA); and Ecological Risk Assessment (ERA). The Queensland Government has provided separate feedback to Defence on the ESA and the HHRA, however, the Queensland Government has not received a draft of the ERA (noting the final report was due by the end of August 2016). The following feedback is therefore limited to the ESA and HHRA. The Queensland Government anticipates having the same opportunity to identify further work once the ERA is released.

While the complexities of the investigation and reporting of contamination at the AACO are acknowledged, any new or revised management plan should include more realistic timeframes for the delivery of reports and requests for responses from Queensland Government representatives.

Objective 1 – Minimise further exposure so that levels in the community return to background levels

The most prominent exposure source for people in contaminated sites is the intake of contaminated ground water. Replacing the ground water with an alternative supply has been an important step in minimising future exposure. The HHRA report provides useful and targeted recommendations on ways residents living in the areas with contaminated ground water can minimise their exposure.

Defence should, however, ensure the ongoing provision of information to the Oakey community on all current and potential uses of affected surface and ground water that should be avoided. In addition, relevant information must be made available to all people on sites of risk (including how they can avoid exposure).

While advice has been provided to minimise consumption of eggs from chickens drinking contaminated ground water, it would be useful to have further information on how long it takes for the eggs to be clear of any contamination if the birds are provided with an alternative, non-contaminated drinking water supply, given that eggs are a good source of protein and vitamins.
The sampling numbers are low for most types of produce which limits the generalisability of the HHRA in relation to consumption of fruit and vegetables produced using contaminated ground water.

It is recommended that Defence undertake sampling of crayfish (yabbies). To date, livestock liver and muscle has been estimated from serum concentrations. However in some cases, the Toxconsult serum model agrees poorly with the published animal transfer studies. It is recommended that tissues from animals at slaughter are sampled and, where possible, cull animals are chosen to examine the influence of age on the tissue concentration. It is also recommended that Total Oxidisable Precursor Analysis (TOPA) is conducted on fish and yabbies from Oakey Creek and any stock if animals are exposed to PFAS via surface water drains from the base as the current drain sampling data ~~analysis is~~ suggest~~ing~~ exposure to Ansulite formulation contaminants that are not effectively ~~directly~~ examined in the risk assessment.

It is recommended that root vegetables be sampled and that further milk is sampled with the age of the animal recorded.

To monitor the effectiveness of exposure minimisation measures over time, Defence should fund an ongoing program of pooled blood serum analysis of samples from the Oakey area.

Future testing must incorporate total oxidisable precursor assay (TOPA) to properly evaluate the potential formation of toxicologically important PFASs through transformation of precursors not detected by standard tests. In this way, potential exposures may be minimised. A conservative approach should be adopted where data gaps and/or uncertainties exist. Further testing should be conducted to more reliably characterise the associated risks.

The contemporary extent of contamination and associated risks needs to be properly understood. Defence should therefore ~~consider~~ conduct~~ing~~ ongoing environmental monitoring sufficient to define any changes in extent and risks over time.

There needs to be consideration given to the provision of alternate water supplies to people whose use of water is precluded by the contamination. This should apply to all existing uses as well as realistic future uses of water protected under t~~T~~*he Environmental Protection Act 1994* and *Environmental Protection Water Policy 2009*.

Objective 2 – Managing community concerns regarding declining land values, reduced amenity and historical exposure

Managing Oakey community concerns over the contamination is important, as people's response to this can impact on their general health and well-being.

The scope of the HHRA has been limited to current and future exposures. There is no information on the impact on individuals who have elevated levels of PFASs in their blood related to past exposure to contaminated ground water. Further information and support is required for individuals who have elevated levels of PFASs in their blood related to past exposure to contaminated ground water.

Some community members wish to have their blood tested for PFASs, and Defence needs to provide a simple pathway for access to this testing, which is not generally available. This pathway should include pre- and post- test counselling of individuals which explains the limitations of the testing.

With the exception of private information, Defence should continue to make all monitoring information and assessments publically available to the Oakey community.

Relevant testing to assess health and environmental exposure risks reasonably raised by community members should be carried out. Defence needs to ensure the Oakey community is advised of remedial measures adopted, and monitor and report on the effectiveness of these measures.

To date, there has not been any advice provide ~~d~~on the effect of PFAs on livestock. Horses in particular are matter of concern for some residents. It is recommended that the effect on livestock is assessed.

Objective 3 – Remediating existing contamination

A key step in minimising future exposure is for Defence to implement mitigation strategies to prevent further off-site contamination, particularly as surface water contamination was identified as an issue in the ESA.

There is limited understanding of the movement of the contaminant into the aquifer. Concentrations in the upper aquifer are higher than the lower aquifer over a large area suggesting movement via surface/overland flow into and through the soil. However, current conclusions are that soil concentrations do not correspond with concentrations in groundwater at the same site. This has been identified as a data gap in the HHRA report.

Uncertainty around the influence of wind as a transport mechanism creates confusion as the predominant wind direction is to the West/Southwest, similar to surface water flow directions. This is also an identified data gap in the HHRA report.

The implications of extraction of potentially contaminated overland flow water by entitlement holders within and downstream of the current investigation area should be investigated as this data is not currently available (*Priority 1*). Contaminated overland flow water may be captured in gully dams.

The entitlement holders utilise surface water for irrigation, stock, domestic, stock intensive and other purposes. Investigation of the implications of extraction of potentially contaminated surface water by entitlement holders in Oakey Creek within and downstream of the current investigation area should be considered (*Priority 2*). For example:

Oakey Creek, within the current contamination extent (Zone/s GOU-01, GOU-05, GOU-07) –

- 2 water harvesting entitlement holders
- irrigation entitlement holders
- Stock or domestic take.

Oakey Creek – downstream approx. 40km (Zone GOU-02):

- 14 water harvesting entitlements

- 22 irrigation entitlements
- Stock or domestic take.

A national process has been undertaken to estimate livestock drinking water concentration below which will not result in animal tissues above FSANZ guidance values. Defence is asked to commit to discussing exposures with Queensland's Department of Agriculture and Fisheries and producers on properties with concentrations above the values and, where necessary, provide alternative stock drinking water.

At a minimum, remediation efforts should also:

- ensure the nature and extent of existing contamination on site is properly characterised for all relevant environmental compartments (e.g. soil, groundwater, surface water drainage, sediments in drains)
- ensure the assessment of contamination also addresses the impacts of the use of Ansulite (post 2005 foam) as well as historic use of 3M Lightwater foam. This will require analysis of the extended suite of PFASs, plus total oxidisable precursor (TOP) assay (reported as the analyses for the resulting perfluorinated carboxylates for C4 to C14 carbon chain length (TOP C4-C14))
- ensure all potential sources of PFAS on site are identified and prioritised in terms of PFAS mass load and potential mobility to groundwater, surface water and biota
- identify remediation options for contaminant sources (e.g. onsite treatment, immobilisation, extraction, disposal)
- promptly attend to readily achievable remediation (e.g. removal of contaminated soil from drainage pathways)
- include temporary storage of contaminated waste which avoids release in to the environment while treatment and disposal options are evaluated
- treatment, transport and disposal of PFAS contaminated material in Queensland must be in accordance with the *Environmental Protection Act 1994* and the *Waste Reduction and Recycling Act 2011*.

Objective 4 – Preventing future contamination including use of contaminated ground water, and newer fire fighting foams)

Alternative pathways for the spread of the PFAS contaminant/s should be investigated, noting that this is currently a gap in the data (*Priority 1*). For example, investigations should focus on the connection through poorly constructed bores or bores that were permitted (prior to legislated standards) to be constructed to access multiple aquifers. (Refer to the Department of Natural Resources and Mines (DNRM) preliminary risk assessment document *'Summary of water bores intersecting the sediments of the Great Artesian Basin Oakey Creek Alluvium groundwater, 2 March 2016'*).

The risk to the Great Artesian Basin (GAB) bores (currently within the plume, adjacent to the plume or expected to be enveloped by the plume (in the next 3-5 years)) pose to the GAB as a local and regional water source should be quantified and remediation / mitigation measures investigated (*Priority 1*). Extension of the investigation of other potentially impacted GAB bores should proceed based either on modelling predictions or as a result of hydrogeological investigations.

Unregistered groundwater bores (i.e. not registered on the DNRM groundwater database) should be investigated (*Priority 1*). Defence investigations have identified a number of unregistered landholder bores. The number of bores, construction details and level of risk are unknown by DNRM. Any scope of work undertaken by Defence should ensure that these bores are appropriately investigated to quantify the risk (if any) they pose to the GAB and any remediation or mitigation measures.

Using the current contaminant plume modelling, the level of natural connectivity to the underlying GAB formations and the subsequent risk this poses to the aquifer and entitlement holders accessing this water source should be investigated (*Priority 1*). In addition to point source risks, Defence also needs to quantify the risk to the GAB groundwater resource from diffuse or natural system connectivity.

In addition to comments offered in Objectives 1 and 2 (above) it will be necessary for Defence to continue to monitor ground water contamination levels for all agricultural enterprises within the current and future investigation areas to ascertain the levels of PFAS. Where that water contamination presents potential for exposure levels which result in exceedance of the FSANZ guidance values, then it would be expected that Defence will risk manage in an appropriate manner.

Measures to prevent future contamination should also address ~~consider~~ the following –

- where contaminants move to new areas or are predicted to do so, affected people should be notified and effective remedial measures implemented to mitigate risks
- the composition of all fire-fighting foams should be fully characterised, including the extended identifiable PFAS suite and TOPA analysis where foams are fluorinated
- all foams and associated wastes must be contained to minimise the likelihood of release into the environment, including via any secondary transfer
- all PFAS contaminated soil, groundwater and waste should be sent to a facility that can properly accept and treat or dispose of such material
- avoid creating new areas of contamination, such as via secondary transfers and enhanced mobilisation of existing contamination
- only use groundwater for uses for which it is suitable
- ensure that any disturbance of contaminated soil minimises risk of contaminating stormwater or releasing contaminated sediments or dusts
- undertake measures to achieve compliance with the Queensland Department of Environment and Heritage Protection's Operational Policy for the Environmental Management of Firefighting Foam.

Suzanne Huxley

From: BRADSHAW Tony <Tony.Bradshaw@ehp.qld.gov.au>
Sent: Monday, 29 August 2016 1:04 PM
To: Darcy Garlick-Kelly; Sophie Dwyer; David Larkings; Janet Cumming; VENTURA Simone; KIND Peter K; WATTS Richard J; MCKAY Adrian; Suzanne Huxley
Cc: Virginia Berry; Justin Carpenter
Subject: RE: Final HHRA responses

Hi Darcy,

please find attached comments on HHRA as requested,

cheers Tony

Issue 1 – Report should acknowledge that its scope is limited to evaluation of current exposure pathways and assessment the associated potential health risks.

The HHRA should acknowledge that its scope (above) does not fully comply with the requirements of the *Environmental Protection Act 1994* and schedule B6 of the *National Environmental Protection (Assessment of Contamination) Measure 1999* to evaluate impact on environmental values protected under the *Environmental Protection (Water) Policy 2009*. This would require it to assess impact to values of groundwater onsite as well as future potential use of waters off-site e.g. freshwater aquaculture.

It is therefore recommended that this clarification of scope be included in the section detailing the objective in the executive summary rather than inferring full consistency with the above legislation. For example, the summary could advise that the scope did not encompass assessment of potential impacts on health of all potential uses of water on and off site.

Issue 2 – Presentation of risks of groundwater consumption
Risks of consumption of groundwater are related to whether consumption would cause exceedance of the tolerable daily intake. Based on the EnHealth 2016 advice that drinking water be allocated 10% as a relative source contribution of the TDI, it is recommended that an additional line be drawn on *Figure 4 Estimated PFOS + PFHxS intakes for residents based on typical exposure parameters* (page 79) that represents the recommendations of Enhealth.
This would be located at a point equivalent to 10% of the TDI. This would give readers of the report an indication of the degree to which the water quality is in excess of relevant health recommendations. This would reinforce the later recommendation against not drinking the groundwater in any areas showing concentrations in excess of the Enhealth guidance.
Given that the Oakey community has experienced past exposures and some members present with higher than average serum concentrations, the objective should be that water suitability be evaluated at least against the Enhealth guidance rather than the TDI (which is based on all source contributions, not just drinking water).
Issue 3 – Risk Assessment for Consumption of Sheep and Cattle
The risk assessment for cattle is based on analysis of blood serum data from stock that have consumed contaminated groundwater. Review of the animal tissue sampling results shows that for rabbits and fish, a wider range of PFAS are detected, particularly longer chain homologues. As the longer chain compounds are of lower solubility than PFOS, PFOA, PFHxS and PFHxA, it would appear that this pattern of exposure relates to contaminated sediment being a more important exposure route. Ingestion of drain sediment containing the more commonly occurring PFAS e.g. PFHxS and PFOS is also not considered.
It is thus considered that the risk assessment does not address risks to sheep, cattle and other stock that may consume water and any entrained soil particles from stormwater drains and other surface waters flowing from contaminated areas of the base. This would differ from stock that consumed clean groundwater from a trough. It is recommended that the risk assessments for stock note this limitation and that this risk be evaluated in the near future.
It is further recommended that this assessment clarify whether the stock that were sampled also consumed forage irrigated with PFAS contaminated groundwater or not. That is, are the predictions related solely to groundwater exposure or is potentially contaminated forage also included.
Issue 4 – Recommendations in Summary Tables e.g. Tables ES2 to ES5 inclusive and in section 9 do not address limitations
The HHRA has a number of limitations that have been noted in the report. It is recommended that where there are limitations, these be included in the summary table.
These would include:

- For consumption of yabbies – No data obtained and hence provide a precautionary recommendation e.g. avoid if have elevated serum concentrations [Note EHP has previously provided comment that yabby contamination concentrations may be greater than fish].
- For use of ground water for aquaculture – No risk assessment undertaken and hence provide a precautionary recommendation.
- For consumption of home grown poultry watered with contaminated groundwater or in contact with contaminated soil - No data obtained and hence provide a precautionary recommendation.
- For consumption of stock that access stormwater drains flowing off the base for water or forage. No data obtained and hence provide a precautionary recommendation.

Issue 5 - Risk Assessment for Future Releases from the site

The HHRA monitored a restricted suite of PFAS in sampling contamination in drainage from the site. Ansulite, the foam used by the Defence Department following the phase out of 3M light water, is a fluorotelomer based AFFF that contains PFAS. An example analysis is provided in the 2013 paper by Backe, Day & Field showed a more comprehensive analysis of Ansul foam circa 2005 with a PFAS content totalling 7,726 mg/L (~ppm) or 0.72%. As mentioned in previous commenst on the HHRA by the Department of Environment and Heritage Protection, it is noted that onsite drainage shows material concentrations of fluorotelomers, indicative of use of the current foam.

Please be advised that to comply with the general environmental duty under the *Environmental Protection Act 1994*, all site assessments need to evaluate commonly identified PFAS as well as those unidentified in standard tests that will ultimately transform to end-point compounds of concern such as PFOA and other fluororoalkyl carboxylic acids (PFCAs) and perfluoroalkyl sulfonates (PFSAs).

The Department of Environment and Heritage Protection's Operational Policy for the Environmental Management of Firefighting Foam and associated explanatory notes provide pertinent advice on this issue.

http://www.ehp.qld.gov.au/assets/documents/regulation/firefighting-foam-policy-notes.pdf

To accurately assess what PFCs are present and the probable level of risk it is not sufficient to analyse only for the current limited suite of about 20 to 28 standard fluorinated organic compounds as it is highly likely that many compounds of concern and their precursors will remain completely undetected. The explanatory notes advise that the recommended analytical suite incorporate:

- *The standard suite of PFCs (including key sulfonates), plus,*
- *Total oxidisable precursor assay reported as the analyses for the resulting perfluorinated carboxylates for C4 to C14 carbon chain length (TOP C4-C14).*

Hence, there is uncertainty in the HHRA about exposures presented by stormwater runoff from the base. It is recognised that this analysis is a recent development. It is therefore recommended that Defence ensures testing be carried out to assess risks due precursors, including use of the current foam, in accordance with the advice in the above Queensland Government policy.

Queensland
Government

Tony Bradshaw
Technical Specialist
Technical Support and Community Response
Regulatory Capability and Customer Service
Department of Environment and Heritage Protection

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Website www.ehp.qld.gov.au

From: Darcy Garlick-Kelly [mailto:darcy.garlick-kelly@premiers.qld.gov.au]
Sent: Monday, 29 August 2016 9:00 AM
To: Sophie Dwyer; david.larkings@health.qld.gov.au; Janet_Cumming@health.qld.gov.au; BRADSHAW Tony; VENTURA Simone; KIND Peter K; WATTS Richard J; MCKAY Adrian; Suzanne Huxley
Cc: Virginia Berry; Justin Carpenter
Subject: Final HHRA responses
Importance: High

Hi all,

A quick reminder to please have your responses to the final HHRA report sent through by **1pm today**.

That will allow time to collate the responses and send through to Defence by **2pm**.

Cheers,
Darcy

Darcy Garlick-Kelly
Policy Officer
Environment Policy
Department of the Premier and Cabinet
Phone: (07) 3003 9487 **Email:** darcy.garlick-kelly@premiers.qld.gov.au
Executive Building, Level 14, 100 George Street, Brisbane QLD 4000
PO Box 15185, City East, QLD 4002
Queensland Government

From: Darcy Garlick-Kelly
Sent: Thursday, 25 August 2016 2:55 PM
To: 'Sophie Dwyer' <Sophie.Dwyer@health.qld.gov.au>; 'david.larkings@health.qld.gov.au' <david.larkings@health.qld.gov.au>; 'Janet_Cumming@health.qld.gov.au' <Janet_Cumming@health.qld.gov.au>; 'Tony.Bradshaw@ehp.qld.gov.au' <Tony.Bradshaw@ehp.qld.gov.au>; 'simone.ventura@ehp.qld.gov.au' <simone.ventura@ehp.qld.gov.au>; 'Peter.Kind@daf.qld.gov.au' <Peter.Kind@daf.qld.gov.au>; 'Richard.Watts@daf.qld.gov.au' <Richard.Watts@daf.qld.gov.au>; 'MCKAY Adrian' <Adrian.Mckay@dnrm.qld.gov.au>
Subject: Oakey HHRA | revised QLD gov review times [SEC=UNCLASSIFIED]

Hi all,

We've received the final HHRA report (see link below)

Please note the new deadline of **2pm Monday 29 August.**

Please have feedback sent through by 1pm to give us time to collate the response.

Cheers,
Darcy

Darcy Garlick-Kelly
Policy Officer
Environment Policy
Department of the Premier and Cabinet
Phone: (07) 3003 9487 **Email:** darcy.garlick-kelly@premiers.qld.gov.au
Executive Building, Level 14, 100 George Street, Brisbane QLD 4000
PO Box 15185, City East, QLD 4002
Queensland Government

From: Harvey, Renee MS [mailto:renee.harvey@defence.gov.au]
Sent: Thursday, 25 August 2016 2:33 PM
To: 'sophie.dwyer@health.qld.gov.au'; 'janet.cumming@health.qld.gov.au'; 'suzanne.huxley@health.qld.gov.au'; 'Richard.Watts@daf.qld.gov.au'; 'tony.bradshaw@ehp.qld.gov.au'; 'MCKAY Adrian' <Adrian.Mckay@dnrm.qld.gov.au>
Cc: Virginia Berry <Virginia.Berry@premiers.qld.gov.au>; Pearce, Vicki MS 1 <vicki.pearce1@defence.gov.au>; Huck, Josephine MS <josephine.huck@defence.gov.au>; JTF633 FCE AMAB Q Store <IMCEAEX-_O=RAAF_OU=AG1_cn=Recipients_cn=DEPRMIDB+20JTF633+20FCE+20AMAB+20Q+20Store@drn.mil.au>; 'Archer, Michael J.' <Michael.J.Archer@aecom.com>; 'Derham, Stuart' <SDerham@golder.com.au>; 'Mitchell, Fran' <FMitchell@golder.com.au>; 'Lee, Frances (Fortitude Valley)' <Frances.Lee@aecom.com>
Subject: FW: Oakey HHRA | revised QLD gov review times [SEC=UNCLASSIFIED]

UNCLASSIFIED

Hi all,

The next version of the Oakey HHRA for your review can be accessed at the link below.

File	Description	Size
0207-AACO-EI2-2016-HHRA_RevE_Redacted.pdf		28,780KB

Please note that the sections that have changed materially since the version you previously reviewed are highlighted.

Also attached is the comments log explaining how your comments on the previous version have been addressed.

Given the timing of this email, we will require any final comments back by 2pm Monday (29 August).

Many thanks,
Renee

Renee Harvey
Co[redacted]nce
M: [redacted]

From: Harvey, Renee MS
Sent: Wednesday, 24 August 2016 08:55
To: 'sophie.dwyer@health.qld.gov.au'; 'janet.cumming@health.qld.gov.au'; 'suzanne.huxley@health.qld.gov.au'; 'Richard.Watts@daf.qld.gov.au'; 'tony.bradshaw@ehp.qld.gov.au'; 'MCKAY Adrian'
Cc: 'Virginia Berry'; Pearce, Vicki MS 1; Huck, Josephine MS; 'Lee, Frances (Fortitude Valley)'; 'Archer, Michael J.'; 'Derham, Stuart'; 'Mitchell, Fran'
Subject: RE: Oakey HHRA | revised QLD gov review times [SEC=UNCLASSIFIED]

UNCLASSIFIED

Good morning all,

Further to my email below, we expect to have the next version of the HHRA through to you by noon tomorrow (25 August).

We would appreciate any final comments back by noon on Monday (29 August).

Material changes to the report will be highlighted so you can more easily see where the main changes have been made.

Many thanks,
Renee

Renee Harvey
Contractor to Defence
M:[redacted]

From: Harvey, Renee MS
Sent: Monday, 22 August 2016 16:31
To: 'sophie.dwyer@health.qld.gov.au'; 'janet.cumming@health.qld.gov.au'; 'suzanne.huxley@health.qld.gov.au'; 'Richard.Watts@daf.qld.gov.au'; 'tony.bradshaw@ehp.qld.gov.au'; 'MCKAY Adrian'
Cc: 'Virginia Berry'; Pearce, Vicki MS 1; Huck, Josephine MS; 'Lee, Frances (Fortitude Valley)'; 'Archer, Michael J.'; 'Derham, Stuart'; 'Mitchell, Fran'
Subject: Oakey HHRA | revised QLD gov review times [SEC=UNCLASSIFIED]

UNCLASSIFIED

Hi all,

Thanks very much for your time last Monday at the workshop to discuss the Queensland Government comments on the Draft Oakey Human Health Risk Assessment.

We indicated at the workshop that the next version of the report addressing your comments would be provided back to you by lunch time tomorrow (23 August) and that we would require any feedback by lunch time Wednesday (24 August).

We will not be in a position to provide you with the next version of the report as planned.

I will be able to indicate a revised timing tomorrow, but wanted to flag this delay with you as soon as possible.

Many thanks,
Renee

Renee Harvey
Contractor to Defence
Environmental Remediation Programs
Department of Defence
M:[redacted]

BP3-2-B021
Brindabella Circuit
Brindabella Business Park
PO Box 7925 Canberra BC 2610

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RTI Release

Suzanne Huxley

From: BRADSHAW Tony <Tony.Bradshaw@ehp.qld.gov.au>
Sent: Thursday, 25 August 2016 3:33 PM
To: Virginia Berry; GLEESON Kelly; WATTS Richard J; KIND Peter K; CONNOR Andrew; HILL Chris; Sophie Dwyer; HOLMES Nigel; Suzanne Huxley; COOK David
Subject: RE: Defence minutes - DNR meeting and ESA workshop

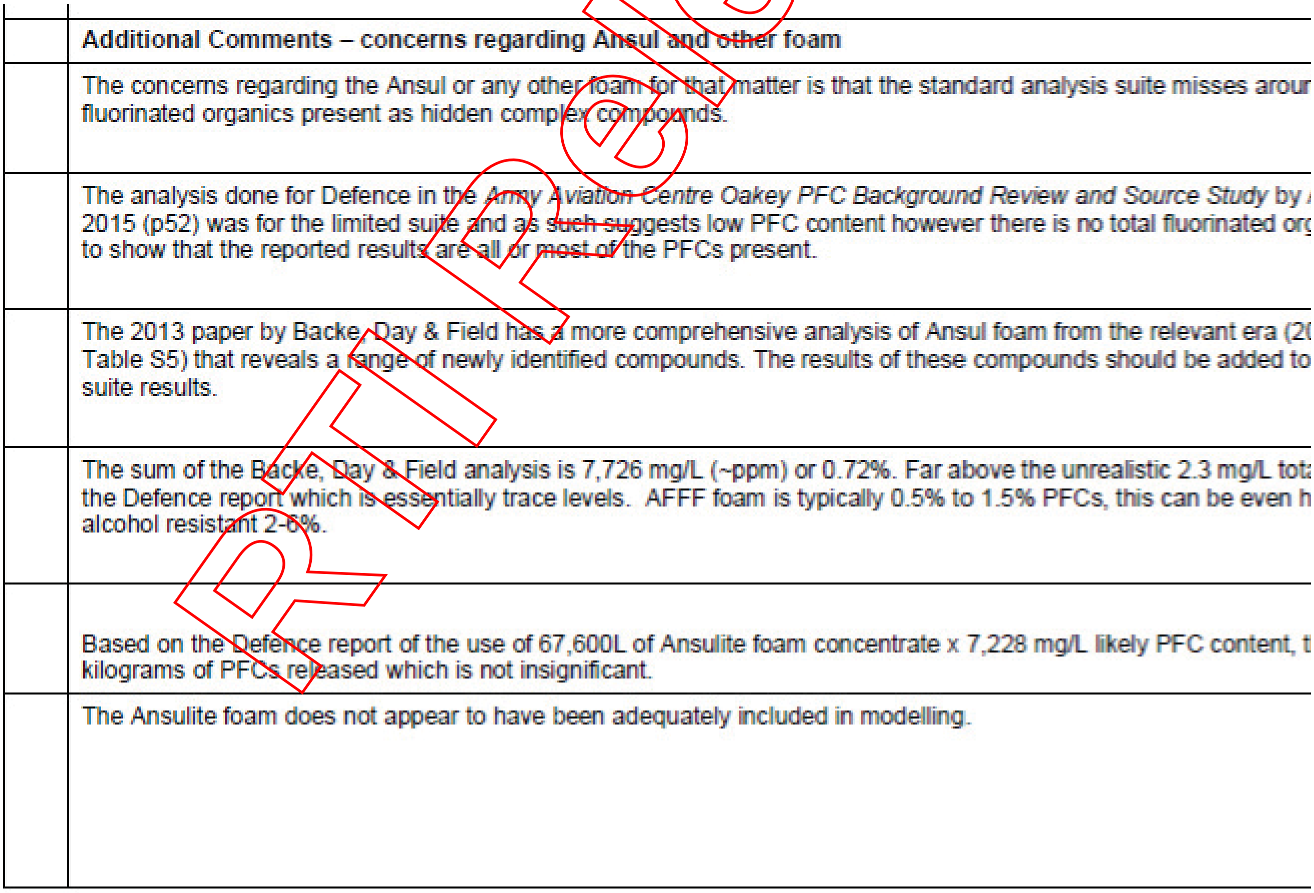
Hi Virginia,

The meeting notes for the ESA workshop defer numerous EHP comments on the Environmental Site Assessment to “Defence for consideration” [see below], but there is no response from Defence to the perceived limitations which EHP has raised. The comments on predictive modelling of groundwater contamination (bottom row) have apparently been deferred to a different scope of work to address.

This means that these particular issues EHP has raised have not been addressed. It would be helpful to know if Defence is going to address these issues.

For other issues EHP have raised, we are advised the assessment will be provided in future the environmental risk assessment report.

Cheers Tony



	Additional Comments – concerns regarding Ansul and other foam
	The concerns regarding the Ansul or any other foam for that matter is that the standard analysis suite misses arour fluorinated organics present as hidden complex compounds.
	The analysis done for Defence in the *Army Aviation Centre Oakey PFC Background Review and Source Study* by 2015 (p52) was for the limited suite and as such suggests low PFC content however there is no total fluorinated org to show that the reported results are all or most of the PFCs present.
	The 2013 paper by Backe, Day & Field has a more comprehensive analysis of Ansul foam from the relevant era (2 Table S5) that reveals a range of newly identified compounds. The results of these compounds should be added to suite results.
	The sum of the Backe, Day & Field analysis is 7,726 mg/L (~ppm) or 0.72%. Far above the unrealistic 2.3 mg/L tota the Defence report which is essentially trace levels. AFFF foam is typically 0.5% to 1.5% PFCs, this can be even h alcohol resistant 2-6%.
	Based on the Defence report of the use of 67,600L of Ansulite foam concentrate x 7,228 mg/L likely PFC content, t kilograms of PFCs released which is not insignificant.
	The Ansulite foam does not appear to have been adequately included in modelling.

Queensland
Government

Tony Bradshaw
Technical Specialist
Technical Support and Community Response
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Department of Environment and Heritage Protection

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Email tony.bradshaw@ehp.qld.gov.au
Website www.ehp.qld.gov.au

From: Virginia Berry [mailto:Virginia.Berry@premiers.qld.gov.au]
Sent: Thursday, 25 August 2016 1:55 PM
To: LEACH Leon; MCKAY Adrian; GLEESON Kelly; BRADSHAW Tony; POTTS Stephen; WATTS Richard J; KIND Peter K; Adrian Jeffreys; CONNOR Andrew; HILL Chris; Don Bletchley; Drew Ellem; MILLER Elton; SANDERS Paul; ROUTLEY Richard; Sophie Dwyer; Suzanne Huxley
Cc: Justin Carpenter; Darcy Garlick-Kelly
Subject: Defence minutes - DNR meeting and ESA workshop

All – please find attached Defence minutes from the meeting with DNRM (1 July) and the Oakey Environmental Site Assessment workshop (11 July 2016).

Please send any feedback on the minutes directly to me.

Cheers, Virginia

From: Harvey, Renee MS [mailto:renee.harvey@defence.gov.au]
Sent: Thursday, 25 August 2016 1:34 PM
To: Virginia Berry <Virginia.Berry@premiers.qld.gov.au>
Cc: Huck, Josephine MS <josephine.huck@defence.gov.au>; 'Derham, Stuart' <SDerham@golder.com.au>; 'Mitchell, Fran' <FMitchell@golder.com.au>
Subject: Oakey | Meeting minutes etc [SEC=UNCLASSIFIED]

UNCLASSIFIED

Hi Virginia,

For your records, please find attached:

- Meeting minutes from the technical briefing held with DNRM on 1 July 2016 regarding the numerical groundwater model prepared for the Oakey ESA. Please note:
    - The minutes confirm that the outstanding drillers logs for the monitoring bores installed by AECOM as part of the ESA were emailed directly to Paul Sanders. Jason Chavasse was asking about these.
    - The DNRM team has mentioned that they have sent through their response to the Defence letter seeking input for the next scope of work at the site. Could this please be re-sent directly to me? We don't have a record of receiving it.

- Meeting minutes from the workshop held with QLD government representatives on 11 July 2011 regarding their comments on the draft Oakey ESA. Please note that these minutes contain the comments log showing how the final ESA addressed comments from the QLD Government.

Please let me know if you have any questions at all.

Thanks
Rene

Renee Harvey
Contractor to Defence
Environmental Remediation Programs
Department of Defence
M: [redacted]

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RTI Release

Purpose of Meeting
The workshop was an opportinty for the Defence Project Team to discuss the Queensland Government's comments on the Stage 2C Environmental Site Assessment (ESA) prepared for the Army Aviation Centre Oakey (AACO). The workshop also served as an opprtunity to discuss how the comments from the Queensland Government will be addressed in the final version of the ESA to be publically relelased.

Name	Position/Organisation
Vicki Pearce	Defence
Renee Harvey	Defence
Josie Huck	Defence
Aaron Anderson	NRF
Fran Mitchell	Project Manager/Contract Adminstrator (Golder Associates)
Stuart Derham	Project Manager/Contract Adminstrator (Golder Associates)
Paul McCabe	Lead Consultant (Stage 2C Investigation) (AECOM)
Frances Lee	Lead Consultant (Stage 2C Investigation) (AECOM)
Andrew Durick	Lead Consultant Subcontractor (Stage 2C Investigation) (AECOM)
Andrew Kohlrusch	Technical Advisor (Stage 2C Investigation) (GHD)
Paul Sanders	DNRM
Adrian McKay	DNRM
Chris Hill	DEHP
Kelly Gleeson	DEHP
Tony Bradshaw	DEHP
Stephen Potts	DAF
Richard Watts	DAF
Peter Kind	DAF
Justin Carpenter	DPC

Item	**Description of Discussion**
1.	**Meeting Summary** • Defence introduced the meeting and confirmed the focus of the meeting was for Defence's project team to provide a response to Queensland Governments comments dated 8 July 2016 on the Stage 2C Environmental Site Assessment (ESA) report (dated 24 June 2016) • Defence had received comments from DNRM and DEHP. • AECOM responded to DNRM and DEHP comments. The response is attached.
2.	**Additional Verbal Questions** The following questions were raised during the workshop. AECOM has responded to these questions in the attached change log document. • Dick Watts (DAF) – requested that Table 3 in the ESA be reviewed (PFOS and PFOA concentrations measured at the fire training ground) • Tony Bradshaw (EHP) - requested that other assessment criteria be considered (eg low and medium reliability ANZECC and international criteria) • Dick Watts (DAF) – requested clarification on ALS TPH analysis (did it include silica gel clean-up) • Dick Watts (DAF) – requested clarification of the chemical data of contaminant source (complex mixture) • Dick Watts (DAF) – requested clarification on the QAQC process (esp. field blanks, removal of Teflon liners • Dick Watts (DAF) – analytical uncertainty - requested clarification on the QC on laboratory spike process, summary of the analytical methods) • Dick Watts (DAF) – requested clarification on how biota results will be reported and if food guidelines will be considered in HHRA
3.	**Actions** • DNRM: provide response to Defence on proposed strategy for next steps in the Environmental Investigation. • Queensland Government: provide final comments to Defence by 4 pm m 12 July 2016 (*it is noted that revised comments were received by EHP on 12 July 2016,*). • AECOM: responded to DNRM and DEHP comments (r*esponse is attached*).

	EHP Initial Review of draft ESA	
	Specific comments	
1.	**Section 2.3.8 - Sensitive local environmental receptors (page 19)**	
	The ESA states that "*The map indicates* (Figure F7) *the nearest wetland with moderate potential for groundwater interaction is an unnamed wetland / dam located approximately 2.5 km south-west of the Site, between Speed Road and Warrego Highway*". However, additional groundwater dependent ecosystems are present (Figure F7) including Oakey Creek which is classed as a Groundwater Dependent Ecosystem (GDE) with moderate potential to rely on surface expression of groundwater. An area of the Site between drain 3 and 4 is also shown to have a low potential for groundwater interaction with GDEs reliant of sub-surface groundwater	**AECOM response:** More detail has been added to this section to clarify.
2	**Section 3.3.3 – Non PFAS suite (page 32)**	
	The ESA described the source of the criteria used to assess the groundwater and surface water quality of a number of non PFAS parameters. However, the groundwater and surface water assessment criteria for BTEXN, TRH, metals, PAH, VOC and SVOC that were adopted for the assessment are not listed. The criteria used in the assessment should be listed within Section 3.3.3.	**AECOM response:** Table 15 has been added, which lists the source of the criteria adopted for each of the non PFAS contaminants. Criteria for individual compounds are contained in the relevant tables of results. Reference to Table 15 has been inserted earlier in the text, in section 3.4.3.
3	**Section 4.3.3 – Groundwater elevation contours, hydraulic gradients and groundwater velocity (page 35)**	
	The ESA states that "*Figure F12 and Figure F13 present the groundwater contour map for the November 2015 round of gauging, which includes measured groundwater elevations at 16 privately owned abstraction bores as well as the newly installed wells*". From this information the groundwater was inferred to flow to the west / south west. This assessment does not include the area south of the Site adjacent to Oakey Creek (see yellow highlighted area in Figure 1). The groundwater flow between drains 2 and 4 may be important in understanding the extent of potential groundwater contamination. The inferred groundwater flow direction and the groundwater contours within the upper and lower Oakey Creek alluvium aquifer need to be expanded to include a representation in the area south of the Site adjacent to Oakey Creek.	**AECOM response:** There are few registered bores to the south of the Site as illustrated in Figure 3.21 of the ESA Appendix F (Groundwater Modelling report), and the well installed by AECOM (MWO-C) was dry, hence limited groundwater elevation data was available for the area to the south of the Site. Note also that there are very few wells with sufficient construction detail to allow interpretation of hydrogeological conditions. AECOM consider the available information is sufficient to assess the extent of potential contamination (which is already confirmed to be at a significant distance from Drains 2 and 4), as the inferred groundwater flow direction is as predicted by regional mapping. S4.3.3 text updated.
4	**Section 4.6.3 – Non PFAS suite (page 40)**	
	Limited groundwater quality data for non PFAS parameters is presented in the ESA. The ESA states that "*The concentrations of coper, nickel and zinc are considered likely to be naturally occurring.*" No evidence or background groundwater quality data was provided in the ESA to justify this statement. Background groundwater quality data should be provided and compared to the concentrations of coper, nickel and zinc observed in the monitoring bores. Additional monitoring bores to the south of the Site may be required to accurately determine the extent of contamination from non PFAS parameters. Total Recoverable Hydrocarbons (TRH) were detected during sampling and was greater than the adopted criteria, however, this result was not discussed (Table 20, page 40). The location of the bores where the concentration of TRH, copper, nickel and zinc were greater than the adopted criteria and the potential source of contamination should be discussed in the ESA.	**AECOM response:** The assessment of non-PFAS CoPC was targeted to groundwater conditions at the site boundary and therefore the discussion of the results is focussed on this aspect. To date, no background data, upgradient of the AACO, has been collected during the course of Defence investigations to establish the concentrations of copper, nickel and zinc. However, discussion has been added regarding the locations and results for analysis of these metals and interpretation of significance in previous investigations. Discussion of the TRH results has also been added.
5	**Section 4.6.4 – Discussion - groundwater results from the ESA (page 40-42)**	
	The concentration of PFAS in 19 groundwater monitoring bores sampled in November 2015, February 2016 and May 2016 by AECOM was discussed in this section. The concentration of PFAS in the 89 private landholder groundwater extraction bores was not discussed in this section. The discussion of the results should be expanded to include the private landholder groundwater extraction bores and the concentration of the non PFAS suite of parameters.	**AECOM response:** Table T6 has been added to Appendix B, which includes all results for private landholder bores. A discussion of these results has also been added to this section. Non PFAS parameters were not analysed in samples collected from private landholder bores.
	There is no groundwater monitoring data between drain 2 and 4 between the southern boundary of the Site and Oakey Creek (see yellow highlighted area in Figure 2). Additional groundwater quality data between drain 2 and 4 could potentially provide further clarity regarding the source of PFOS and PSAS within the private landholder groundwater extraction bores south of drain 2 on the southern side of Oakey Creek and inform the solute transport model.	**AECOM response:** As illustrated in Figure 3.21 of the ESA Appendix F (Groundwater Modelling report), there are few registered bores to the south of the Site, and the well installed by AECOM (MWO-C) was dry, hence limited groundwater analytical data was available for the area to the south of the Site. Collection of additional samples from residential bores in this area is not considered to be required to assess the extent of the contaminant plume – it is considered that this is well established from the available data. Collection of additional samples would also be limited by the availability of private landowner bores in this area.
6	**Section 4.7.3 – Non-PFAS in surface water in drainage lines (page 43)**	
	Limited non PFAS parameter surface water quality data is presented in the ESA. Copper and zinc were greater than the adopted criteria, however, this result was not discussed (Table 22). The surface water locations where copper and zinc were greater than the adopted criteria and the potential sources should be discussed in the ESA. Background surface water quality data should be	**AECOM response:** The assessment of non-PFAS CoPC was targeted to surface water runoff at the site boundary and therefore the discussion

	provided and compared to non PFAS parameter concentrations observed in the drainage lines. Additional surface water samples to the south of the Site may be required to accurately determine the extent of contamination from non PFAS parameters.	of the results is focussed on this aspect. Discussion has been added regarding the copper and zinc results. Background surface water data was only collected for PFAS contaminants.
7	**Section 5.4 – Solute Transport Model (page 58**	
	The ESA stated that "*This southern extension of the PFAS plume indicates other processes, in addition to groundwater flow, have significantly influenced the shape and extent of the PFAS detection area. These other processes are considered to be a function of:* · *groundwater pumping from bores drawing groundwater from the Oakey Creek Alluvium;* · *discharge of PFAS impacted surface water runoff along unlined stormwater drains that flow southwards from the Site into Oakey Creek; and* · *mobilisation of PFAS solutes along Oakey Creek during periods of flow and resultant solute recharge from this stream flow into the groundwater system at considerable distances downstream of the Site.* *The solute transport model was ultimately designed to take these other processes into account.*" It was also noted in the ESA that the uncertainty related to the spatial and temporal distribution of the PFOS and PFAS source has a potential to affect the solute transport model calibration. As identified above, additional groundwater monitoring between drain 2 and 4 between the southern boundary of the Site and Oakey Creek could provide more data to improve the accuracy of the estimated extent of contamination and further calibrate the solute model to the south of the Site.	**AECOM response:** It is unlikely that having additional data in this area would have significantly changed the calibration result of the model. The calibration has identified that there are areas to the west of the site and around the landfill that have not matched well, and this is because the potential sources at these locations and the specific mechanics of spreading into these locations have not been simulated in the solute transport model.
	AACO Oakey environmental site assessment DNRM_DSITI comments	
	A number of comments for consideration/ discussion are tendered from DNRM and DSITI. It is noted that the comments from the DNRM Comments Log (issued 27 May 2016) with Responses have been predominantly addressed	
	General Comments	
8	It is noted that the Marburg Sandstone outcrops within the model area. While the sequence is closer to model boundary and unlikely to influence the prediction, it presence should be identified in the Groundwater Model report	**AECOM response:** More detail on the Marburg Sandstone has been added to Section 5.3.2.
9	Comment 4 from DNRM Comments Log (issued 27 May 2016) with Responses is still relevant for future versions	**AECOM response:** Defence will consider utilisation of hydrochemistry in any future revisions of the model, particularly as heterogeneity in spatial variability is added to the parameter distributions. This analysis would add little to the current model setup and does not impact on the model meeting the current objectives.
10	It is noted the transition zone is missing in areas close to the source and Figure 8.18 identifies a potential movement to the GAB Aquifers underlying the Oakey Creek Alluvium. This is an important consideration for further assessment previously requested by DNRM in our meeting of the 28 April 2016	**AECOM response:** Where the transition zone is thin, the model has predicted the movement on contaminant into the Walloon Coal Measures and Main Range Volcanics, however there are no measurements of contaminant in these units under the Site. Detections in bores in these units are located to the south and west of the base and are considered to be most likely due to poor bore construction connecting alluvial sediments to the underlying basement rock within the bore hole.
11	Is there a plan for future revisions of the groundwater model (say 3-5 yrs time) to incorporate data gathered and improved understanding of both groundwater hydrogeology and solute transport?	**AECOM response:** The results of the ESA provide an improved understanding of the nature, extent and potential migration of PFAS contamination within the Investigation Area based on data collected between 2014 and early 2016. It is understood Defence will undertake further assessment to refine the current understanding of PFAS contamination arising from AACO within the Investigation Area. Information from further assessment would enable an improved understanding of local hydrogeology and solute transport. It is understood the outcomes of this ESA will inform these further assessments and will also inform ongoing environmental monitoring and future management decisions in relation to PFAS contamination arising from AACO. The further assessments and ongoing monitoring programs of work will be developed in consultation with the Queensland Government.
12	Is there a program for future expansion of the Groundwater monitoring network?	**AECOM response:** As above
	Comments on the Environmental Site Assessment	
13	2.3.7 – Discussion on Oakey TWS – Groundwater was the only source on TWS prior to the pipeline from Toowoomba (Wetalla). Discussion appears to only be focussed on recent use	**AECOM response:** Section 2.3.7 has been revised to include the available information on historical town water supply from anecdotal sources and from the TRC submission to the Senate Inquiry.

	Comments on Appendix C – Monitoring Well installation and Groundwater Monitoring Report	
14	4.6.3.1 – It is noted the groundwater gauging from November 2015 was not repeated for private and Departmental monitoring bores. Is there a reason for this? These bores would have a history of monitoring.	**AECOM response:** The November 2015 GME included gauging of selected privately owned bores (those with known well construction details) and the new monitoring wells installed by AECOM. This data was considered sufficient to assess groundwater flow direction. Gauging was also undertaken of the groundwater elevation at the newly constructed monitoring wells during sampling events in February and May 2016, as per standard groundwater sampling procedures. Removal of bore infrastructure was required for the initial event, and further inconvenience to local landholders was not considered necessary for the subsequent events.
	Comments on Appendix F – Groundwater Model Report	
15	Figure 3.30. The scale of the Figure and the number of water levels plotted make interpretation difficult. It is noted that there appears to be limited movement in the water levels and virtually no water levels response to the 2011 floods. This appears to be inconsistent with departmental monitoring bores which rose for a period of up to 3 years after this event. Is this just an interpretation error on DNRM's part or is there a reason.	**AECOM response:** Figure 3.30has been updated to include a selection of representative (in range of water levels and frequency of measurements) bores, while the entire available site monitoring data is tabulated in Appendix F of the modelling report. All the bores that have data that straddle the flood event show a rise in groundwater elevation. Text has been added to the report to clarify this.
16	A clarification for Comment 14 from the DNRM Comments Log (issued 27 May 2016) with Responses. Agree with the comment, however, as a clarification, the groundwater contours in the revised Figure 3.38 suggest mounding upstream of the 400m contour, well upstream of Oakey. Future versions should provide context to this.	**AECOM response:** This figure has been updated.. This was a result of combining data over a period of several years. The data available at one bore was limited and representative of a high water level, while more data was available for other bores and produced a more representative average.
17	Section 3.4.5.1 – There is valuable interpretative discussion on stream recharge and aquifer response in this section, which appears to indicate stream recharge is an important component of recharge in this section. While it is noted that that it is likely that this process has become less important over time due to silting etc, hydrographs still suggest responses to stream recharge. It is suggested that this component of recharge need further investigation in any future model revision.	**AECOM response:** Potential importance of stream recharge for some sections of Oakey Creek is noted. The requirement for stream recharge conceptualisation will be considered in Defence's determination of additional environmental scopes of work for the site.
18	Figure 7.9 and 7.11 – Modelled heads appear to provide good representation of observed water levels, however, are less responsive post 2011 flood event. Can this be explained?	**AECOM response:** The reduced amplification of response to the 2011 flood event is due to the filtering of the rainfall to produce a more realistic rate of recharge. No additional recharge was applied to represent the ponded water that would have remained after the flood event and been available for continual recharge during that period. The requirement for this will be considered in Defence's determination of additional environmental scopes of work for the site.
19	Section 9 – Model Uncertainty – The figures in this section are difficult to interpret, particularly for the general public. Is there a simpler way of representing this?	**AECOM response:** The number of figures has been rationalised and the zone of potential predictions for the 95% linear confidence interval has been shaded to make this clearer.
	Comments on Draft Environmental Site Assessment July 2016 (QLD EHP, via email on 12 July 2016)	
	Background The draft report advises that criteria adopted in the assessment are primarily sourced from the Defence document '*Contamination Directive #8 Interim Screening Criteria 'Consistency of Toxicology or Ecotoxicology based Environmental Screening Levels for PFOS, PFOA, 6:2 FTS'* (DCD8) dated 19 May 2015. The Defence document notes that these interim assessment criteria 'are to be used at all Defence sites until further notice'. In the absence of a numerical criterion for a specific exposure scenario within the DCD8 document, or a more relevant document being sourced, AECOM has supplemented the DCD8 interim criteria with internationally published criteria. **Issues** The assessment criteria do not properly consider and evaluate international guidance, in some cases, where they adopt a particular source, use out-dated information from that source and do not consider all relevant environmental values. Examples are discussed below. **Assessment Criteria for Drinking Water** The assessment of drinking water adopts the values from the US EPA 2009 preliminary health advisory. It notes that these have been superseded but does not utilise the more up to date criteria. The more recent US EPA drinking water criteria are more stringent and adopt an additive approach to PFOA and PFOS contamination. The additive approach for addressing cumulative impacts of PFAS contamination is also used in other jurisdictions including Germany, Denmark and Sweden. For example, the Swedish National Food Agency (the Agency responsible for drinking water in Sweden) has adopted an action level of 90 ng/L i.e. 0.09 µg/L. This was based on allowing 10% of tolerable daily intake for drinking water and infant consumption of contaminated drinking water. The action level applies to the sum of the seven PFCs characterised as contaminating the groundwater. These are:	**AECOM response:** The following text has been added to Section 3.4: *DCD8 (May 2015) was published by Defence to provide an interim benchmark to support the progression of relevant activities on the Defence estate in a nationally consistent manner.* *In the absence of formal Australian human health or ecological assessment criteria for these emerging contaminants, the DCD8 values were adopted from a working draft of the Cooperative Research Centre for Contamination Assessment and Remediation of the Environment (CRC CARE) Technical Report: Assessment, Management and Remediation Guidance for Perfluorooctane sulfonate (PFOS) and Perfluorooctanoic acid (PFOA) (March 2015).* *It is acknowledged that these values will be subject to further review prior to the CRC CARE report being finalised. Relevant work to establish assessment criteria consistent with current Australian science policy (enHealth 2012, ANZECC 2000 and NEPM 2013) is also currently being undertaken by the Australian Department of the Environment and enHealth.* *It is noted that overall risks to human health or the environment from PFAS cannot be evaluated simply by comparison of reported PFAS concentrations with the DCD8 criteria, because PFAS have the potential to bioaccumulate within the food chain and the DCD8 criteria do not take into consideration the potential for bioaccumulation via all potential pathways.* As published assessment criteria were not available for all potentially complete pathways, Defence has commissioned AECOM to complete a quantitative HHRA and ERA, which gives consideration to cumulative risks via multiple exposure pathways and chemicals. On this basis, Tier 1 criteria were not used to screen out results in the risk assessments (ie all detected concentrations were assessed in the HHRA and ERA). As such, consideration of the range of screening criteria suggested is not considered necessary for the ESA report.

1. Perfluorbutane sulfonate (PFBS)
2. Perfluorhexane sulfonate (PFHxS)
3. Perfluoroctane sulfonate (PFOS)
4. Perfluorpentanoate (PFPeA)
5. Perfluorhexanoate (PFHxA)
6. Perfluorheptanoate (PFHpA)
7. Perfluoroctanoate (PFOA)

See: http://www.livsmedelsverket.se/livsmedel-och-innehall/oonskade-amnen/miljogifter/pfas-poly-och-perfluorerade-alkylsubstanser/riskhantering-pfaa-i-dricksvatten/?_t_id=1B2M2Y8AsgTpgAmY7PhCfg==&_t_q=dricksvatten+pfaa&_t_tags=language:sv,siteid:67f9c486-281d-4765-ba72-ba3914739e3b&_t_ip=203.8.131.32&_t_hit.id=Livs_Common_Model_PageTypes_ArticlePage/_ee4f9186-1e8a-452c-a83d-fc93d9de77b3_sv&_t_hit.pos=1

and

http://ehp.niehs.nih.gov/isee/p2-548/

It is noted that some of these additional PFAS are present in groundwater.

Assessment Criteria for Residential Soil

The assessment adopted 2009 values for PFOS and PFOA are from US EPA Region 4 (Southeast United States) for a residential land use. These criteria are based on US EPA 2009 preliminary reference doses, which have been superseded in the latest US EPA drinking water guidelines.

US EPA region 4 residential screening levels for PFOS and PFOA developed in 2009 are 6 mg/kg and 16 mg/kg respectively. These were based on reference doses of 80 ng/kg-day and 200 ng/kg-day for PFOS and PFOA respectively.

https://archive.epa.gov/pesticides/region4/water/documents/web/pdf/final_pfc_soil_screening_values11_20_09.pdf

More recent reference doses advised by the US EPA are as follows:

- PFOA - 20 ng/kg/day – see https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final-plain.pdf
- PFOS - 20 ng/kg/day – see - https://www.epa.gov/sites/production/files/2016-05/documents/pfoa_health_advisory_final-plain.pdf

It can be seen that the 2009 reference doses are factors of 4 and 10 lower for PFOS and PFOA respectively. If the residential soil criteria were calculated using the same assumptions but including these revised reference doses, the corresponding soil criteria would be 4 and 10 times lower for PFOS and PFOA. That would translate to 1.5 mg/kg and 1.6 mg/kg for PFOS and PFOA residential soil screening levels respectively.

The assessment also fails to mention and evaluate the 2015 approach of the Danish Environmental Protection Agency. The Danish EPA has developed soil quality criteria of 0.39, 0.39 and 1.3 mg/kg for PFOS (and derivatives), PFOSA and PFOA respectively.

See - http://www2.mst.dk/Udgiv/publications/2015/04/978-87-93283-01-5.pdf

Where there is more than one contaminant present, an additive concentration approach is advised in which the sum of the ratios of contaminants present to screening levels must be less than one. This is based on the assessment that the toxicological profiles and the toxicological potency of PFOA and PFOS are very similar and it seems justified to use an additive approach for these substances when evaluating situations where PFOA, PFOS and PFOSA occur in the soil at the same time.

Thus for complying to a composite soil quality criteria the addition of the *concentration / limit value* ratios for PFOA, PFOS and PFOSA should be kept below the value of 1. This concentration addition approach can be written as:

PFOA (conc. / QCsoil) + PFOS (conc. / QCsoil) + PFOSA (conc. / QCsoil) < 1

or

PFOA (conc. mg/kg) / 1.3 mg/kg + PFOS (conc. mg/kg) / 0.39 mg/kg + PFOSA (conc. mg/kg)/0.39 mg/kg < 1

Where there are additional PFAS, an alternative approach was recommended where the limit value for PFOS as the most toxic substance also is used for the total content (the sum) of other perfluorinated alkyl acids. Using such an approach for PFOA and the PFAS listed in appendix 2 (these are PFHpA, PFNA, PFBS, PFHxS, PFDS, PFHxA) is considered as a conservative and protective approach.

It is noted that some of these PFAS have been found in the extended PFAS suite analysed, including some found at comparatively high concentrations e.g. PFHxS.

Assessment Criteria for Recreational Water

The assessment adopts the approach in the 2008 NHMRC *Recreational Water Guidelines* that specify a screening approach in which a substance occurring in recreational water at a concentration of 10 times that stipulated in the drinking water may merit further consideration'. This approach is supported, although there is concern that drinking water criteria adopted in the assessment do not take into account more recent international guidance or consider cumulative impacts.

Assessment Criteria for Protection of Human Consumers from Consumption of Aquatic Food

There is no evaluation of this receptor in the assessment. There is guidance available internationally from the Dutch National Institute for Public Health and the Environment (RIVM), which has derived Environmental Risk Limits (ERLs) for perfluorooctane sulfonate (PFOS) in fresh and marine surface waters.

For PFOS, the RIVM calculated a maximum permissible concentration of 0.65 ng/L for freshwater for consumption of fish by humans. This value could be utilised as a screening value, amended as necessary to account for any differences in underlying assumptions e.g. fish consumption rates.

Assessment Criteria for Protection of use of water for stock watering

This environmental value of water is not mentioned in the assessment and no screening value provided. For Primary Production – stock watering, the Australian and New Zealand Guidelines for Fresh and Marine Water Quality – Primary production (ANZECC 2000) advise in section "4.3.5 Pesticides and other organic contaminants" that "i*n the absence of adequate information derived specifically for livestock under Australian and New Zealand conditions, it is recommended that the drinking water guidelines for human health be adopted.*

This would be an interim screening approach until further detailed assessment was undertaken.

Assessment Criteria for Aquatic Ecosystems – Toxicity Issue

The assessment used the value of 5.1 µg/L for PFOS and 2,900 µg/L for PFOA from Giesy et al., 2010. These values were derived from is based on the calculation acute-chronic ratio (ACR) value from toxicity tests. This is a legitimate approach under the ANZECC 2000 water quality guidelines to develop interim guidance where there is insufficient data to develop a species sensitivity distribution.

There is draft guidance available which utilises the species sensitivity approach preferred under the ANZECC guidelines. These are referenced in the West Australian guidelines. For slightly to moderately disturbed ecosystems, these values are 0.13 µg/L and 220 µg/L for PFOS and PFOA respectively. See https://www.der.wa.gov.au/images/documents/your-environment/contaminated-sites/guidelines/Guideline-on-Assessment-and-Management-of-PFAS-.pdf

It is important that the above criteria address toxicity, not risks of bioaccumulation to higher trophic levels.

Assessment Criteria for Bioaccumulation in higher trophic level fauna

It is important that the ecological criteria address risks of bioaccumulation to higher trophic levels. Birds are air breathing organisms and do not have the same potential loss mechanism of exchange/excretion across respiratory membranes as do fish and crustacea. They are not necessarily protected by considering bio-accumulation studies of fish and crustaceans.

The same paper adopted for aquatic toxicity i.e. Giesy et. al. (2010) contains calculated criteria to protect avian wildlife based on bioaccumulation and adverse impact concentrations on higher level consumers. See http://www.usask.ca/toxicology/jgiesy/pdf/publications/JA-539.pdf

Giesy et. al. calculated a screening level to protect avian wildlife of 47 ng PFOS/L.

Assessment Criteria for Ecological Health of Terrestrial Soil

The assessment utilises a PFOS value is from the UK Environment Agency 2009, which

provides criteria based on a low reliability PNEC as a conservative interim screening value. This PNEC is based on 95% protection of species.

There is no international guidance mentioned for PFOA and 6:2 FtS, although approaches are mentioned wwhich are not supported by AECOM.

Norway has adopted the following screening values based on toxicity studies in earthworms. The experiments were performed by Stubberud (2006) resulted in NOEC-values of 10 and 16 mg/kg soil PFOS and PFOA, respectively. For 6:2 FtS an EC10 of 21 mg/kg was calculated

	NOEC (mg/kg)	EC10 (mg/kg)	Assessment factor	**PNEC (ng/g dw)**
PFOS	10		100	**100**
PFOA	16		100	**160**
6:2 FtS		21	100	**210**

	An assessment factor of 100 was used to derive predicted no effect concentrations according to European Union recommendations for derivation from a NOEC based on a single long-term toxicity test. See: http://www.miljodirektoratet.no/old/klif/publikasjoner/2444/ta2444.pdf Stubberud, H. 2006. Økotoksikologiske effecter av PFOS, PFOA og 6:2 FTS på meitemark (Eisenia fetida). (in Norwegian, English summary). Report TA 2212/2006. Norwegian State Pollution Control Authority, PB 8100 Dep, 0032 Oslo. See http://www.miljodirektoratet.no/old/klif/publikasjoner/kjemikalier/2212/ta2212.pdf It is suggested that the values for Norwegian guidance PFOA and 6:2 FtS should be adopted in preference to that discussed but not accepted in the assessment. The UK guidance for PFOS would appear more reliable as it is based on a species sensitivity approach. These terrestrial soil ecological assessment criteria should also be applied to dry drainage channels which appear to have been evaluated using residential soil criteria. **Recommendations** The assessment criteria section needs to discuss current internationally available guidance rather than just adopting what is prescribed in defence department documents. Where there is a divergence between what is adopted as assessment criteria and current internationally available guidance, the rationale for preferring the criteria adopted should be explained. Various environmental values potentially impacted by the contamination as mentioned in the site conceptual model do not have corresponding assessment criteria e.g. stock water, human consumer of fish and aquatic life. These should be identified. Bioaccumulation in wildlife such as birds should also be addressed by relevant criteria. For drinking water, additive approaches which recognise that the contamination involves more than just a single contaminant should be used, as occurs in overseas jurisdictions. This is especially relevant given the results from testing of the extended PFAS suite.	
	Additional Comments – concerns regarding Ansul and other foam	
	The concerns regarding the Ansul or any other foam for that matter is that the standard analysis suite misses around 90% of the fluorinated organics present as hidden complex compounds.	**AECOM response:** Comments of this nature are to be provided directly to Defence for consideration.
	The analysis done for Defence in the *Army Aviation Centre Oakey PFC Background Review and Source Study* by AECOM in 2015 (p52) was for the limited suite and as such suggests low PFC content however there is no total fluorinated organics analysis to show that the reported results are all or most of the PFCs present.	Comments of this nature are to be provided directly to Defence for consideration.
	The 2013 paper by Backe, Day & Field has a more comprehensive analysis of Ansul foam from the relevant era (2005) (Supp Info Table S5) that reveals a range of newly identified compounds. The results of these compounds should be added to the standard suite results.	Comments of this nature are to be provided directly to Defence for consideration.
	The sum of the Backe, Day & Field analysis is 7,726 mg/L (~ppm) or 0.72%. Far above the unrealistic 2.3 mg/L total (0.023%) in the Defence report which is essentially trace levels. AFFF foam is typically 0.5% to 1.5% PFCs, this can be even higher for AR alcohol resistant 2-6%.	Comments of this nature are to be provided directly to Defence for consideration.
	Based on the Defence report of the use of 67,600L of Ansulite foam concentrate x 7,228 mg/L likely PFC content, that is 489 kilograms of PFCs released which is not insignificant.	Comments of this nature are to be provided directly to Defence for consideration.
	The Ansulite foam does not appear to have been adequately included in modelling.	The numerical groundwater modelling undertaken to date only considers PFOS and PFOA. Ansulite has been reported as containing very low concentrations of these compounds. Ansulite was simulated to be in use at the base from 2002 to 2011, however it was assumed that most of the material was collected in storage tanks, with only 5% making it to the environment,. as represented in the solute transport model. Feedback to be considered during Defence's assessment of additional environmental scopes of work developed for the site.

The table below was provided with Qld Government comments.

X:Y Ft mg/L	ANSUL 2005	Chemguard 2010	Angus 2002	National 2003	Buckeye 2009	Fire Service Plus NR
4:2	26		25			
5:1:2					2,000	
5:3			4,900		530	
6:2	6,100	11,000	2,200	6,742		8,253
7:3					610	
7:1:2					4,700	
8:2	1,100	24	170	1,009		2,576
9:1:2					1,900	
9:3					430	
10:2				450		830
12:2				210		430
Total mg/L	7,226	11,024	7,295	8,411	10,170	12,089
<=C6	6,126	11,000	7,125	6,742	2,530	8,253
>=C7	1,100	24	170	1,669	7,640	3,836
<=C6 %	85%	100%	98%	80%	25%	68%
>=C7 %	15%	0.2%	2.3%	20%	75%	32%
Total g/L	7.226	11.024	7.295	8.411	10.17	12.089
Total % (w/w)	0.72%	1.10%	0.73%	0.84%	1.02%	1.21%

Verbal comments from ESA workshop

Comment:	**AECOM response:**
Dick Watts (DAF) – requested that Table 3 in the ESA be reviewed (PFOS and PFOA concentrations measured at the fire training ground)	Table 3 has been reviewed and some edits made. The units were correct.
Tony Bradshaw (EHP) - requested that other assessment criteria be considered (eg low and medium reliability ANZECC and international criteria)	More detail on the adopted criteria has been added to section 3.3.
Dick Watts (DAF) – requested clarification on ALS TPH analysis (did it include silica gel clean-up)	Silica gel clean up was not included in the TRH analysis – a statement has been added to the report in Section 4.6.3 to clarify this.
Dick Watts (DAF) – requested clarification of the chemical data of contaminant source (complex mixture)	Chemical data has been checked and the values presented in table 4 are considered to adequately summarise those available in the literature.
Dick Watts (DAF) – requested clarification on the QAQC process (esp. field blanks, removal of Teflon liners	More information has been added to section 3.2. Detailed sampling methodologies and QC/QA information are included in the sampling reports in Appendices C, D and E – cross references have been added.
Dick Watts (DAF) – analytical uncertainty - requested clarification on the QC on laboratory spike process, summary of the analytical methods)	Detail on laboratory QC/QA and laboratory methods are included in the sampling reports in Appendices C, D and E.
Dick Watts (DAF) – requested clarification on how biota results will be reported and if food guidelines will be considered in HHRA	Biota results will be reported in the HHRA. The use of generic assessment criteria (such as food guidelines) in a "Tier 1" screening step for selection of chemicals of potential concern (CoPC) is not considered appropriate for the HHRA because PFAS have the potential to bioaccumulate within the food chain. Available Tier 1 guideline values have not been established which are protective of the potential for bioaccumulation via all potential pathways. The identification of CoPC for the quantitative HHRA was therefore based on the availability of toxicity reference values (TRV, which are numerical values derived from toxicity dose-response studies) derived in a manner consistent with relevant Australian science policy, for those PFAS detected above the laboratory Limit of Reporting (LOR).

Australian Government
Department of Defence
Estate and Infrastructure Group

MEETING MINUTES

Project Name:	**Army Aviation Centre Oakey - Groundwater Model Technical Briefing**		
Date of Meeting:	**1 July 2016** **(0930 am – 1230 pm)**	*Location:*	**AGE Offices, Level 2, 15 Mallon Street Bowen Hills, Brisbane**
Minutes Prepared By:	**Golder**		

Purpose of Meeting

The briefing focused on the technical aspects of the groundwater model prepared for the Army Aviation Centre Oakey (AACO) Stage 2C Environmental Site Assessment (ESA). The ESA includes an assessment of the nature and extent of per- and poly fluoroalkyl substances (PFAS), specifically perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA) in soil, sediment, surface water and groundwater within and surrounding the AACO.

Name	Position/Organisation
Renee Harvey	Defence
Fran Mitchell	Project Manager/Contract Administrator / Golder Associates
Stuart Derham	Project Manager/Contract Administrator / Golder Associates
Greg Swain	Lead Consultant / AECOM
Andrew Durick	Lead Consultant Subconsultant to AECOM / AGE
Stefan Charteris	Technical Advisor / GHD
Leon Leach	QLD DSITI
Adrian McKay	QLD NRM
Paul Sanders	QLD NRM

Item | **Description of Discussion**

1. **Introduction**

- Defence confirmed the groundwater model would form an appendix to the Environmental Site Assessment (ESA) report.
- The ESA report is currently with the Defence Minister and is expected to be released to the Qld Government shortly.
- Defence's project team's response to DNRMs comments on the Groundwater Model Plan will be included with the transmission of the ESA.
- The project schedule will be revised after the ESA is sent to the Qld Government to provide revised dates for:
  - The workshop to discuss comments from the Qld government on the ESA.
  - Community information sessions.

2. **Groundwater Model – Summary of Technical Briefing to DNRM**

- AECOM's sub-consultant (Australasian Groundwater & Environmental Consultants (AGE)) provided the meeting group with an overview of the AACO Stage 2C Groundwater Model task including: task objectives, modelling approach, summary of flow calibration, summary of solute calibration, model outcomes.
- The objectives of the modelling were to:
  - Understand and attempt to simulate the historical development of PFOS / PFOA solute plumes from the Site; and then
  - Undertake a simulation to examine a 'non-remediation scenario' to predict future plume movement without any remedial strategies.
- Summary of modelling approach:

Project Name:	**Army Aviation Centre Oakey - Groundwater Model Technical Briefing**		
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Minutes Prepared By:	**Golder**		

Item **Description of Discussion**

    - As the model development progressed, it became apparent that the most material data gap was the uncertainly associated with the temporal and spatial distribution of the historical contaminant source.
    - A simplified homogeneous representation of aquifer parameters was adopted.
    - The flow model was initially calibrated and then tweaked during the solute transport calibration.
- Summary of Model Calibration:
    - Flow Calibration – good fit for the response of groundwater levels.
    - Issues associated with the solute transport model calibration included:
        - Uncertainty related to the spatial and temporal distribution of the PFOS and PFOA source areas;
        - The actual heterogeneity in the Oakey Creek alluvium vs. the model representation, although it is noted that the higher end of a reasonable parameter range for the Oakey Creek alluvium was adopted in the model;
        - The potential affect of flooding and then infiltration through soil to the water table on plume development not being simulated;
        - The potential for impacted irrigation return flow to facilitate plume migration and spreading of an already diffuse plume;
        - Potential influence of the Oakey Waste Landfill Facility; and
        - The total contaminant load could be larger than the available data indicates, meaning that the model would be prone to under predicting the detection extent. It is however noted that the total load of contaminant is applied directly to the water table, which is considered conservative and means potential over prediction of concentrations at certain points in the aquifer based on remaining contaminant in the soil.
- Limitations of the flow calibration included:
    - Homogeneous representation of a heterogeneous system.
    - Simplified recharge representation with no irrigation return flow.
    - Assumption about groundwater extraction where no data exists.
- Limitations of the solute calibration included:
    - Key sources do not match the 'plume' extent towards the west.
    - Has not captured all the potential sources in the model setup.
- Three scenarios were undertaken using the calibrated model, and a fourth scenario was devised based on not matching all the detections west and southwest of the site:
    - Scenario 1 (base case) simulated a 'non-remediation scenario' to predict future PFOS and PFOA plume movement without any targeted/planned remedial strategies.
    - Scenario 2 (climate variability) simulated plume movement in the event that future average rainfall is higher or lower than the base case scenario.
    - Scenario 3 (pumping variability) simulated plume movement in the event that groundwater pumping ceases in areas where the PFOS and PFOA plumes are currently detected and predicted by the base case scenario.
    - Scenario 4 (detection area) simulated plume movement using the currently mapped detection area as the starting point. This also simulated a 'non-remediation scenario'.
- Summary:
    - There is uncertainty in the contaminant source temporal and spatial distribution. However, as a conservative measure the entire estimated load of PFOS and PFOA has been applied directly to the water table.
    - Model calibration has not been able to replicate all contaminant detections at all sample points within the PFOS and PFOA detection areas.
    - The model has been used to identify other potential mechanisms for the observed detections.

Project Name:	**Army Aviation Centre Oakey - Groundwater Model Technical Briefing**		
Date of Meeting:	**1 July 2016** **(0930 am – 1230 pm)**	*Location:*	**AGE Offices, Level 2, 15 Mallon Street Bowen Hills, Brisbane**
Minutes Prepared By:	**Golder**		

Item	Description of Discussion
	○ These mechanisms require further investigation before they can be reliably simulated. ○ Recognising that the flow model is conservatively calibrated, it was used with the detection area mapping to provide conservative estimates of where the plume might migrate to in 10 and 100 years without implementation of remediation strategies. ○ This simulation suggests that the plume is not likely to migrate far in the next 10 years, but does show some migration after 100 years.
3.	**Actions** • Defence: Confirm project schedule and date of workshop with Qld Government to discuss comments from the Qld government on the ESA and community information sessions. **Complete** • DNRM: Provide feedback direct to Defence on what DNRM would like to be included in the next stage of investigation at AACO. **DNRM to please confirm if this has been sent, if so, please re-issue to Renee Harvey directly.** • Defence: Resend Defence letter which responded to DNRM memo regarding investigating the GAB. **Complete** • Defence: Resend groundwater bore logs (drilled by AECOM for Stage 2C Investigation) to DNRM. **Complete (email sent to Paul Sanders 7 July 2016)**

Suzanne Huxley

From: BRADSHAW Tony <Tony.Bradshaw@ehp.qld.gov.au>
Sent: Monday, 8 August 2016 5:05 PM
To: Chris McKenna; Sophie Dwyer; Janet Cumming; VENTURA Simone; KIND Peter K; WATTS Richard J; MCKAY Adrian; David Larkings; Suzanne Huxley
Cc: Justin Carpenter; Virginia Berry; CONNOR Andrew; HILL Chris; COOK David; GLEESON Kelly
Subject: RE: Technical Working Group - HHRA Preliminary Working Group Comments
Attachments: Technical Working Group - Technical Report Summary of Comments - HHRA - EHP.docx

Hi Chris,

please find attached a summary of work so far as requested,

cheers Tony

From: Chris McKenna [mailto:Chris.McKenna@premiers.qld.gov.au]
Sent: Monday, 8 August 2016 11:44 AM
To: Sophie Dwyer; Janet_Cumming@health.qld.gov.au; BRADSHAW Tony; VENTURA Simone; KIND Peter K; WATTS Richard J; MCKAY Adrian; david.larkings@health.qld.gov.au; Suzanne Huxley
Cc: Justin Carpenter; Virginia Berry
Subject: Technical Working Group - HHRA Preliminary Working Group Comments

All

As discussed, please complete the attached template and return to myself ASAP today.

I will collate for Sophie as a whole-of-government discussion supporter at tomorrow's IDC.

Please keep your dots high level and succinct.

Regards

Chris McKenna

Environment Policy
Department of the Premier and Cabinet

P 07 3003 9324
Executive Building, Level 14, 100 George Street, Brisbane QLD 4000
PO Box 15185, City East, QLD 4002

Queensland Government

Queensland Government Interdepartmental Committee for Fluorinated Firefighting Foam

Technical Working Group
Preliminary Summary of Comments
Department of Defence Oakey Human Health Risk Assessment

<Environment and Heritage Protection >

Report Conclusions

No Issues

- Groundwater use for drinking and other high exposure scenarios is an important risk

Not Supported

- Those aspects of the report's conclusions/findings that your agency does not support
-

Points of Contention

- Although contending all PFAS were evaluated, several PFAS detected on and off site in groundwater are not included in risk calculations e.g. PFHpA, PFBS.
- The HHRA does not assess of environmental values protected under the Water EPP, only current off-site uses. This approach of excluding uses future potential use e.g. freshwater aquaculture is inconsistent with the contaminated land NEPM and the EP Act.
- HHRA fails to adequately address impact EP Act environmental values e.g. groundwater on site by failing to evaluate relevant risks on the basis that management controls will be implemented so there is no need. This approach is inconsistent with the contaminated land NEPM and the EP Act.

Limitations

- There has been limited sampling of some environmental media with reduce representativeness and reliability of risk estimates e.g. eggs, root vegetables, yabbies.
- Potential future risks for current use of PFAS containing Ansulite fire-fighting foam not adequately addressed.
- PFAS detected on and off site in groundwater are not included in risk calculations, which occurs in overseas jurisdictions e.g. Danish EPA.
- The sensitivity assessment does not address impacts on the assessment of adopting the lower PFOA TDI/TRV adopted by the US EPA in 2016.
- The discussion and evaluation of serum PFAS concentrations include the risk guidance values (HBM-1) recently published in May 2016 in Germany by the HBM commission of the German environmental agency. The levels adopted at which the German agency considers PFAS exposures should be minimised are low compared to HHRA guidance concentrations. This may be due to the fact that epidemiological studies are not heavily weighted in the assessment.
- Doesn't address future potential uses of water

Suzanne Huxley

From: CONNOR Andrew <Andrew.Connor@ehp.qld.gov.au>
Sent: Thursday, 30 June 2016 3:55 PM
To: Suzanne Huxley; Sophie Dwyer
Cc: Janet Cumming
Subject: RE: Health statements

Thank you - I've sent them up the chain and will forward a copy once they've been endorsed here.

Andrew Connor
Executive Director
Industry, Development & South Queensland Compliance Environmental Services and Regulation Department of Environment and Heritage Protection
----
P 07 3330 6335
Level 8, 400 George Street, Brisbane QLD 4000 GPO Box 2454, Brisbane QLD 4001

-----Original Message-----
From: Suzanne Huxley [mailto:Suzanne.Huxley@health.qld.gov.au]
Sent: Thursday, 30 June 2016 3:36 PM
To: Sophie Dwyer; CONNOR Andrew
Cc: Janet Cumming
Subject: RE: Health statements

Hi Sophie and Andrew

I'm happy with them also.

Regards

Suzanne

-----Original Message-----
From: Sophie Dwyer
Sent: Thursday, 30 June 2016 3:15 PM
To: CONNOR Andrew
Cc: Janet Cumming; Suzanne Huxley
Subject: Re: Health statements

Good, from my point of view. Suzanne, Janet?

Sent from my iPad

> On 30 Jun 2016, at 3:03 PM, CONNOR Andrew <Andrew.Connor@ehp.qld.gov.au> wrote:
>
> ok - how about these points on a slide under heading 'National Health Guidance - enHealth'
>
> - In chronic exposure studies on lab animals, PFOS and PFOA have shown adverse effects on liver, gastrointestinal tract and thyroid hormones. The applicability of these studies to humans is not well established.

> - In humans, research has not conclusively demonstrated that PFOS and PFOA are related to specific illnesses, even under conditions of occupational exposure. Recent studies have found possible associations to some health problems, although more research is required.
> - Continued exposure to PFOS and PFOA results in accumulation in the human body. Due to the potential for accumulation and uncertainty about health effects, it is prudent to reduce exposure as far as is practicable.
>
>
> Andrew Connor
> Executive Director
> Industry, Development & South Queensland Compliance Environmental
> Services and Regulation Department of Environment and Heritage
> Protection
>
> ---
> ---
> -
> P 07 3330 6335
> Level 8, 400 George Street, Brisbane QLD 4000 GPO Box 2454, Brisbane
> QLD 4001
>
>
> -----Original Message-----
> From: Sophie Dwyer [mailto:Sophie.Dwyer@health.qld.gov.au]
> Sent: Thursday, 30 June 2016 2:47 PM
> To: CONNOR Andrew
> Cc: Janet Cumming; Suzanne Huxley
> Subject: Health statements
>
> Last two paras and 1st para on 2nd page summarise the health effects
> well. You could draw from them. I am tied up in meetingotherwise I
> would edit
>
>
>
> https://www.health.gov.au/internet/main/publishing.nsf/Content/A12B57E
> 41EC9F326CA257BF0001F9E7D/$File/PFC-guidance-statements-15March2016.pd
> f
>
>
>
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From: BRADSHAW Tony <Tony.Bradshaw@ehp.qld.gov.au>
Sent: Thursday, 23 July 2015 12:23 PM
To: Rebecca Richardson; Matthew Boyd; Penny Hutchinson; Peter Boland; Greg Jackson; Sophie Dwyer; Suzanne Huxley; Janet Cumming; WATTS Richard J; POTTS Stephen; HILL Chris; DELZOPPO Lindsay; MCLENNAN Stacey; CHAVASSE Jason; SANDERS Paul; GOUDIE Steve; Louise.mahoney@premiers.qld.gov.au; Rebecca.seen@justice.qld.gov.au; Peter.mcgarry@justice.qld.gov.au; VARDY Suzanne; COOK David; HOLMES Nigel; GLEESON Kelly
Subject: RE: Documents regarding the Oakey Incident
Attachments: FoamPolicyExplanatoryNotesV2-0a.pdf; PolicyStakeholderLetter2ndDraft.pdf; QLD_Policy-FirefightingFoamsDraft2-0.pdf

Hi Rebecca,

Further to the interdepartmental meeting on Oakey yesterday, EHP undertook to provide a copy of technical information underpinning the Department's Draft Policy on Fire Fighting Foams. This develop jointly with the Western Australia Department of Environmental Regulation and subject to public consultation through 2015.

Some of the key sections are in the explanatory notes. These include:

Composition of Fire Fighting Foams and PFCs (pages 3 – 6)
Health Implications (pages 17 – 18)
Persistence (Table 2.9A – page 16)

Any comment and feedback Queensland Health have on health aspects of the explanatory notes and policy would be appreciated. It is noted that an approach for comment has been made previously so this advice may be in train.

Cheers Tony

Tony Bradshaw
Technical Specialist
Technical Support and Community Response
Regulatory Capability and Customer Service
Department of Environment and Heritage Protection

P 07 3330 5704
Level 9, 400 George St, Brisbane QLD 4000
GPO Box 2454, Brisbane QLD 4001

Email tony.bradshaw@ehp.qld.gov.au
Website www.ehp.qld.gov.au

Please consider the environment before printing this email

From: BRADSHAW Tony
Sent: Tuesday, 21 July 2015 4:30 PM
To: 'Rebecca Richardson'; Matthew Boyd; Penny Hutchinson; Peter Boland; Greg Jackson; Sophie Dwyer; Suzanne Huxley; Janet Cumming; WATTS Richard J; POTTS Stephen; HILL Chris; DELZOPPO Lindsay; MCLENNAN Stacey; CHAVASSE Jason; SANDERS Paul; GOUDIE Steve; Louise.mahoney@premiers.qld.gov.au; Rebecca.seen@justice.qld.gov.au; Peter.mcgarry@justice.qld.gov.au; VARDY Suzanne; 'COOK David'; HOLMES Nigel; GLEESON Kelly
Subject: RE: Documents regarding the Oakey Incident

Hi Rebecca,

EHP has prepared comments on the Oakey Incident documents which Lindsay has asked me to provide to you and the Oakey meeting participants.

The comments are in track changes with an explanatory comment.

Cheers Tony

Queensland
Government

Tony Bradshaw
Technical Specialist
Technical Support and Community Response
Regulatory Capability and Customer Service
Department of Environment and Heritage Protection

P 07 3330 5704
Level 9, 400 George St, Brisbane QLD 4000
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Email tony.bradshaw@ehp.qld.gov.au
Website www.ehp.qld.gov.au

s.73 - irrelevant information

s.73 - irrelevant information

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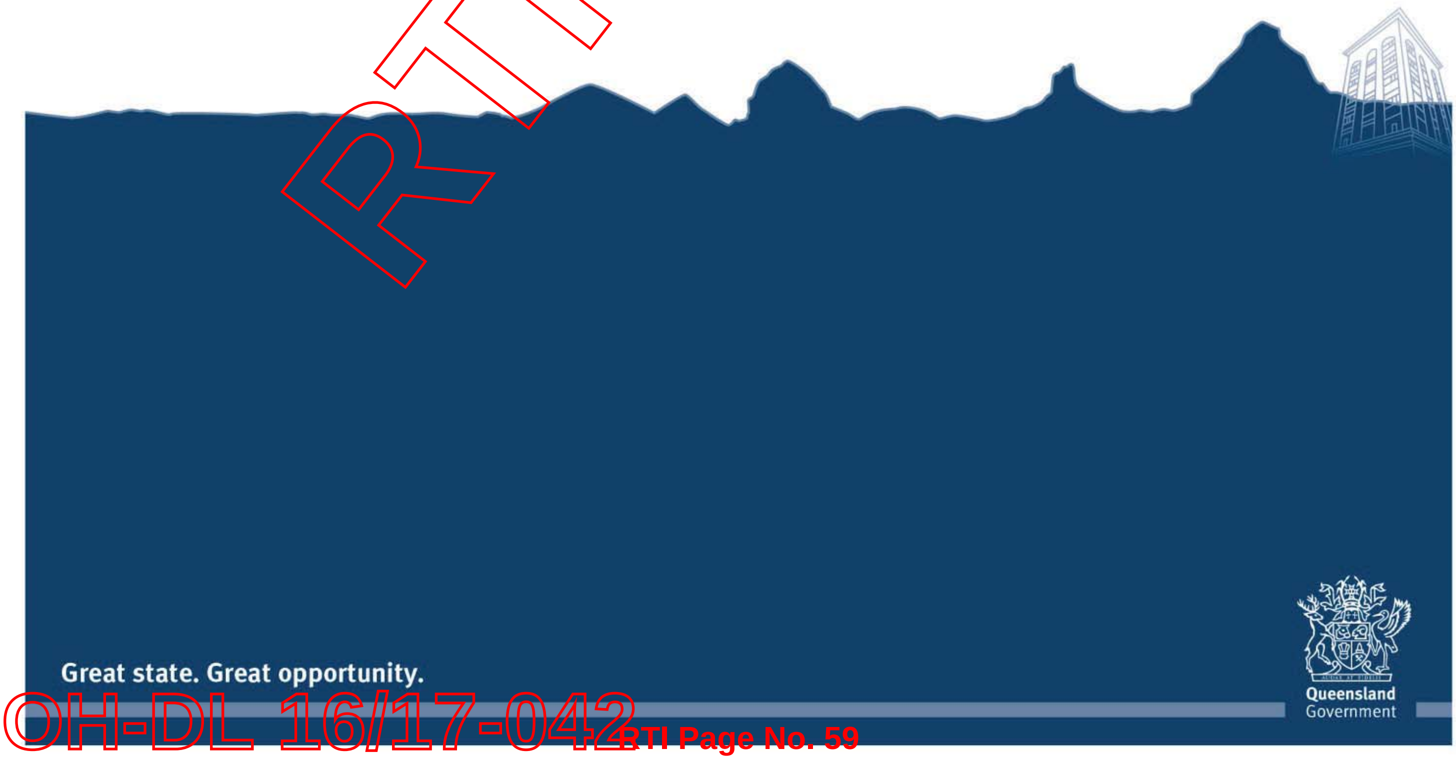
RTI

Department of Environment and Heritage Protection

Managing Firefighting Foam Policy

Explanatory Notes



Great state. Great opportunity.

Queensland
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Prepared by: Incident Response Unit, Department of Environment and Heritage Protection

Disclaimer

Version 1.3 – December 2014

www.EHP.qld.gov.au ABN 46 640 294 485

Contents

Managing Firefighting Foam Policy

Explanatory Notes

1 Introduction

These Explanatory Notes provide background and clarification to the Management of Firefighting Foams Policy document and should be read in conjunction with that Policy.

There has been very significant evidence emerging in recent years regarding the potential for firefighting foams to have detrimental effects on environmental and other values during incident responses, training, maintenance activities and waste disposal when handled improperly and released to the environment via air, bodies of water, soils and groundwater.

Existing environmental legislation in Australia requires that any person, corporation or organisation carrying out an activity must take all reasonable and practicable measures to prevent or minimise the potential for environmental harm or pollution, having regard to the current state of technical knowledge for the operation or activity and other relevant matters.

The state-of-knowledge regarding the potential for firefighting foams to cause adverse effects on health and the environment has improved significantly in the last decade, as has the development of technologies and procedures to mitigate these effects. There now needs to be a consolidation of information and standards to guide users towards achieving best practice and ensuring that appropriate protective measures are taken and the liabilities for health, the environment and the user are properly assessed and managed.

1.1 Background

A significant review has been undertaken by the Queensland Department of Environment and Heritage Protection in conjunction with the Western Australian Department of Environmental Regulation into the potential impacts of the use of firefighting foams. This has included a very extensive literature review and consultation with regulators and experts in Australia and overseas.

The Foam Management Policy sets out foam management standards that must be met, the baseline information that must be provided and relevant test standards so that users, regulators and incident responders have a reasonable basis on which to make appropriate comparisons, decisions and choices when it comes to selecting a firefighting foam for any particular situation and to be able to plan for, and respond to incidents so that environmental and other values are least likely to be compromised.

While the review and the development of the Policy have primarily focussed on the potential for environmental harm or pollution to be caused, they also take into consideration human health impacts, workplace health and safety, firefighting performance, public amenity and economic issues.

Consultation with a range of stakeholders on the draft Policy raised a variety of general and specific issues, and additional information which has been considered in redrafting of the Policy and in the coverage and content of these Explanatory Notes.

1.2 Firefighting foam

Firefighting foam refers to concentrates and their aqueous solutions that are used in the production of streams or blankets of air/gas-filled bubbles to suppress flammable vapours, increase water penetration, reduce static spark generation, control or extinguish fires, and prevent re-ignition by excluding air and cooling the fuel.

Firefighting foams may be used to prevent or extinguish fires involving:

- **Class A** fires – in carbonaceous combustible materials, such as wood, paper, fabric, plastics and rubber, where the fire can be deep-seated in the burning material.
- **Class B** fires – of flammable and combustible liquids or spills such as liquid hydrocarbon fuels and polar solvents where the fire and vapours are on the surface of the liquid.

Foam for these hazards and fires can be supplied by fixed piped systems or portable foam-generating systems and be applied by methods such as portable hose streams using hand-held foam nozzles, large-capacity monitor nozzles or subsurface injection systems [1].

For the purposes of this review and the Policy the terms *Class A foam* and *Class B foam* are used to refer to the foams formulated for dealing with Class A and Class B fires respectively. Where the term *firefighting foam* is used it refers to both Class A and Class B foams unless specified.

1.3 Principles

The use of any firefighting foam has the potential to have a combination of environmental, health and economic impacts and it is ultimately the end-user that will bear the range of risks and liabilities associated with its albeit infrequent use.

When deciding on the most appropriate foam for a particular application, and whether or not current systems are adequate, the user needs to carefully consider the full range of short-term and long-term risks and factors that influence how they can achieve and demonstrate best practice [2] in the balance of the options for protection of *Life-Environment-Property*.

Firefighting systems need to be thought of in terms of not only their day-to-day utility and firefighting performance during incidents but also in terms of the entire lifecycle cost [3] including the potential downstream acute and chronic effects of releases on the environment, human health and amenities. It is acknowledged that every situation is different and to achieve the appropriate balance the user needs to take into consideration:

- Firefighting performance for the particular application.
- Adjacent environmental values (e.g. wetlands, bodies of water, soils, groundwater, etc.).
- Adjacent urban, amenity and economic values that could be impacted.
- Pathways for contaminants to affect adjacent values.
- The particular foam formulation (every foam is unique in its composition).
- Potential impacts of available firefighting system and foam options.
- Ability to capture, contain and treat wastes and firewater.
- Operational practicalities and compatibilities.
- Workplace health and safety (day-to-day and during incidents).
- Compliance with regulatory requirements and standards.
- Potential costs for clean-up and harm or pollution caused on and off site.
- Costs and practicalities of waste treatment and disposal.
- Corporate reputation and liability.
- Value for money through a cost-benefit analysis.

There will never be a "one-size-fits-all" firefighting foam system that achieves all-round best-practice protection for all circumstances and considerations. In attempting to properly assess the risks inherent in their situation and to make a confident and informed choice when selecting an appropriate system and foam, users are often significantly hampered by a lack of information, incomplete knowledge and inadequate and/or inaccurate advice in one or more relevant areas.

The benchmark for overall best-practice in firefighting foam formulations and their use has changed progressively in recent years. Increasing awareness of the adverse health and environmental effects associated with some compounds in formulations, which were previously regarded as acceptable or were the only available effective solution at the time, has in particular driven the need for continuous improvement and development of better practices and formulations with more acceptable health and environmental outcomes.

This now means that many users need to reassess their risks and liabilities and, where necessary, improve their performance against current and emerging best practice. In some cases this can be easily achieved but for some foam users this represents a significant operational and cultural challenge.

In addition to the increased knowledge about the behaviour and effects of pollutants generally there is now also a greater expectation by the community that health, amenity and environmental values will be properly considered and protected with decisions based on comprehensive and balanced risk assessments that take all relevant factors into account.

2 Impacts of firefighting foams

All firefighting foams are of concern if they are released to the environment; there is no such thing as a completely “*environmentally friendly*” foam as espoused in some marketing brochures. Firefighting foams depend on a variety of compounds and formulations for their effectiveness. Some of the compounds and formulations can have adverse short and long-term impacts on the environment, human health and other values if released. The primary areas of concern are:

- **Biochemical oxygen demand** – The majority of foams have high BOD potential. Dissolved oxygen levels in water can be quickly and severely depleted when the organic components of released foam are degraded by the action of naturally occurring aerobic micro-organisms.
- **Acute (short-term) toxicity –** Toxicity from detergents, solvents and other components in foams can result in immediate adverse effects on organisms in the area of the release.
- **Persistence –** Foams may contain compounds of known, suspected and currently unknown toxicity that do not degrade in the environment and/or are not readily metabolised in biota and can therefore exert potential toxic effects over a long period of time. Persistence also means that there is an increased risk of long-term exposure, bioaccumulation of toxic compounds and dispersal with impact on areas, some at great distances from the source of the discharge.
- **Bioaccumulation –** The uptake of toxic compounds by organisms and the accumulation of them at higher concentrations than in the environment and the potential for the compounds to be passed up, and further bioconcentrated up the food chain (trophic magnification).
- **Chronic (long-term) toxicity –** The often overlooked potential for compounds to cause long-term impacts on humans and organisms, especially if they are persistent and/or bio-accumulative, even though their short-term toxicity may be relatively low.

2.1 Composition of firefighting foams

While the composition of firefighting foams includes general classes of compounds, such as surfactants, solvent, stabilisers and thickeners, each foam formulation is unique and differs in the combination of specific ingredients. The potential for adverse health and environmental effects depends on the physical and toxic effects of particular ingredients as well as the synergistic effects of them in combination in the formulation.

For example, a biocide or preservative that is not critical to firefighting performance may have particular toxic effects in the environment that may be enhanced or suppressed when in combination with other unrelated compounds.

Fluorinated organic compounds have been a common ingredient in firefighting foams for many decades, being the key to the properties and effectiveness of many foams. There has been a growing awareness in recent times of the potential for very significant, long-term and widespread adverse human health and environmental effects of these compounds, with the result that this has brought them under particular scrutiny and has driven a reassessment of their use, fate and effects.

The growth in knowledge about the behaviour and effects of fluorinated organic compounds is illustrated by the number of papers published from 1994 to 2012 on environmental aspects of these compounds (Figure 2.1 A) [4].

This shows the recent rapid increase in interest and information about fluorinated organic compounds over the last decade but also illustrates the almost complete lack of knowledge in the public domain about the environmental (and probably health) effects between the time of their first use in the 1960s to the early 2000s.

PFOS and PFOA are the most often mentioned fluorinated organic compounds and are well recognised as being of serious concern for human health and the environment [5,6,7,8].

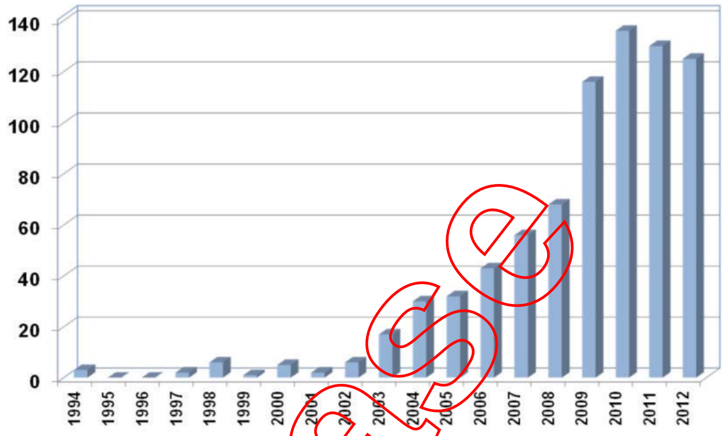


Figure 2.1 A – Number of published papers on perfluoroalkyl substances 1994 to 2012 (Redrawn from Trojanowicz & Koc [4])

The casual reader could be forgiven for thinking that PFOS and PFOA are the only two compounds of concern [9,10]. It is very important, however, to realise that there are thousands of possible fluorinated organic compounds [11,4], and of those in use in some firefighting foams only about 50 have been publicly identified so far [12,13,14] with a similar or greater number of others currently remaining unidentified [15,16].

In a 2013 study of 12 samples of foam used in Canada [17,15] (and elsewhere) comparison of the concentrations of known fluorosurfactants with the total organofluorine content found less than 10% of the fluorosurfactants were identified in half of the samples and generally less than 50% of fluorinated organic compounds were identifiable overall (in some samples 0% were identified). PFOS was also a significant component in 6 of the 12 samples.

This has very significant implications for risk assessment of the possible environmental effects of these as well as other fluorinated foams if these results are typical as a very significant proportion of the fluorinated organic compounds used are largely unknown and undeclared in Safety Data Sheets (SDS) or elsewhere. Consequently the behaviour, impact and fate of those fluorinated compounds in the environment are largely unable to be assessed.

There are two main groups of fluorinated organic compounds. These materials are commonly termed *per*-fluoroalkyl and *poly*-fluoroalkyl substances (collectively the PFASs) [9] and it is important to appreciate the difference between *poly*-fluorinated and *per*-fluorinated compounds (Figure 2.1 B), their occurrence in foams and how they subsequently behave in the environment:

- *Per-fluorinated* compounds – such as PFOS and PFOA, where all the atoms in the main carbon chain are fluorinated and do not hydrolyse, photolyse, or biodegrade under environmental conditions.
- *Poly-fluorinated* compounds – such as 8:2 fluorotelomers that have carbon atoms in the chain that are not fully fluorinated but on release to the environment will *partially* degrade resulting in a per-fluorinated end-point compound.

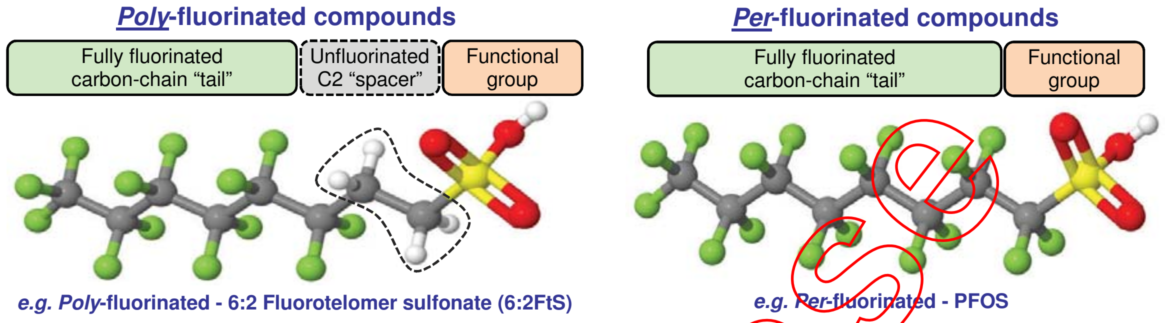
Where the compound is described as an *X:Y* fluorotelomer the "*X*" denotes the number of fully or per-fluorinated carbon atoms and the "*Y*" denotes the number of non-fluorinated carbon atoms [9,18]. The general structure of *poly*-fluorinated compounds consists of three groups [19]:

- an oleophobic/hydrophobic fully-fluorinated carbon-chain tail, (CF_3-CF_2-CF_2-...)

- a non-fluorinated organic “spacer” (dimethylene group, $-CH_2-CH_2-$)
- a hydrophilic functional group (sulfonate, betaine, carboxylate, etc.).

Per-fluorinated compounds do not have the middle, unfluorinated spacer group.

Fluorotelomers compounds are commonly composed of a straight-chain with an even number of fluorinated carbons (C6, C8, C10, etc.) with the unfluorinated C2 dimethylene group ($-CH_2-CH_2-$) between the fluoralkyl chain and the end group that determines the compound’s functionality [18,20]. For example, *6:2 fluorotelomer sulfonate* (Figure 2.1 B) or *8:2 fluorotelomer betaine*.



Atoms–Green=Fluorine, Grey=Carbon, White=Hydrogen, Red=Oxygen, Yellow=Sulphur, non-fluorinated carbon atoms circled
(Molecule graphics generated by www.chemspider.com)

Figure 2.1 B – Generalised structures of *poly-* and *per*-fluorinated compounds (acids shown)

Tables 2.1 A & 2.1 B illustrate the diversity and complexity of some of the fluorinated organic compounds thus far identified as occurring in fluorinated foams or resulting from partial degradation. This is further complicated by some compounds also being able to exist as different structural arrangements of branched and unbranched isomers. PFOA ($C_8HF_{15}O_2$), for example, has 39 possible structural isomers, that is, 39 different arrangements of the chain lengths and branches for the same molecular composition [21].

Additionally, those fluorotelomers with eight carbons in the perfluorinated chain (e.g. 8:2FtS), including some found in foams advertised to be “*PFOS and PFOA free*”, will partially degrade in the environment relatively quickly producing PFOA as the major end-point *perfluorinated* degradation product [22,23,24]. A similar process occurs for the larger, more toxic higher homologue compounds such as 10:2FtS which degrades to perfluoro decanoic acid (PFDA) (Figure 2.5.1 A). Such compounds that degrade to a perfluorinated compound are termed *precursor* compounds e.g. *PFOA precursors* or *PFOS precursors*.

Table 2.1 A – Fluorinated organic compounds (FOCs) in samples of firefighting foams and groundwater	
Place & Field (2012)–FOCs in MilSpec AFFF [12]	
Perfluorobutane sulfonamide amine (C4)	4:2 fluorotelomer sulfonamide betaine
Perfluoropentane sulfonamide amine (C5)	5:1:2 fluorotelomer betaine
Perfluorohexane sulfonamide amine (C6)	5:3 fluorotelomer betaine
Perfluorobutane sulfonamide amino carboxylic acid (C4)	7:1:2 fluorotelomer betaine
Perfluoropentane sulfonamide amino carboxylic acid (C5)	7:3 fluorotelomer betaine
Perfluorohexane sulfonamide amino carboxylic acid (C6)	8:2 fluorotelomer sulfonamide amine
Perfluorohexane sulfonamide ammonio dicarboxylic acid	8:2 fluorotelomer sulfonamide betaine
Perfluoropentane sulfonamide ammonio dicarboxylic acid	8:2 fluorotelomer thio hydroxy ammonium
Perfluorohexane sulfonic acid (PFHxS)	8:2 fluorotelomer thioether amido sulfonic acid
Perfluoroheptane sulfonic acid (C7 PFHpS)	8:2 fluorotelomer thioether amino carboxylic acid
Perfluorooctane sulfonic acid (C8 PFOS)	9:1:2 fluorotelomer betaine
6:2 fluorotelomer sulfonamide amine	9:3 fluorotelomer betaine
6:2 fluorotelomer sulfonamide betaine	10:2 fluorotelomer sulfonamide betaine
6:2 fluorotelomer thio hydroxy ammonium	10:2 fluorotelomer thioether amino carboxylic acid
6:2 fluorotelomer thioether amido amino carboxylic acid	
6:2 fluorotelomer thioether amido sulfonic acid	

Table 2.1 B – Fluorinated organic compounds (FOCs) in samples of firefighting foams and groundwater

Backe, Day & Field (2013)–FOCs in AFFF and groundwater [13]

4:2 fluorotelomer thioamido sulfonate
6:2 fluorotelomer thioamido sulfonate
8:2 fluorotelomer thioamido sulfonate
4:2 fluorotelomer sulfonate (4:2FtS)
6:2 fluorotelomer sulfonate (6:2FtS)
8:2 fluorotelomer sulfonate (8:2FtS)
Perfluoroheptly sulfonamido amine (C7)
Perfluorooctyl sulfonamido amine (PFOS precursor [25])
Perfluorheptyl sulfonamide amino carboxylate (C7)
Perfluoroctyl sulfonamide amino carboxylate (C8)
Perfluorobutyl sulfonamido amine (C4)
Perfluoropentyl sulfonamido amine (C5)
Perfluorohexyl sulfonamido amine (C6)
Perfluorbutyl sulfonamide amino carboxylate (C4)
Perfluorpentyl sulfonamide amino carboxylate (C5)
Perfluorohexyl sulfonamide amino carboxylate (C6)
Perfluorobutyl sulfonate (C4 PFBS)
Perfluoropentyl sulfonate (C5 PFPeS)
Perfluorononyl sulfonate (C9 PFNS)
Perfluorodecyl sulfonate (C10 PFDS)
Perfluorobutyl carboxylate (C4)
Perfluoropentyl carboxylate (C5)
Perfluorohexyl carboxylate (C6)
Perfluoroheptyl carboxylate (C7)
Perfluorooctyl carboxylate (C8 PFOA)
Perfluorononyl carboxylate (C9)
Perfluorodecyl carboxylate (C10)
Perfluoroundecyl carboxylate (C11)
Perfluorododecyl carboxylate (C12)
Perfluorotridecyl carboxylate (C13)
Perfluorotetradecyl carboxylate (C14)
(Fluorinated organic compounds common to both studies)
(6:2 fluorotelomer thio hydroxy ammonium)
(6:2 fluorotelomer sulfonamido betaine)
(8:2 fluorotelomer sulfonamido betaine)
(10:2 fluorotelomer sulfonamido betaine)
(12:2 fluorotelomer sulfonamido betaine)
(5:1:2 fluorotelomer betaine)
(7:1:2 fluorotelomer betaine)
(9:1:2 fluorotelomer betaine)
(5:3 fluorotelomer betaine)
(7:3 fluorotelomer betaine)
(9:3 fluorotelomer betaine)
(Perfluorohexyl sulfonate (C6))
(Perfluoroheptyl sulfonate (C7))
(Perfluorooctyl sulfonate (C8 PFOS))

In general the focus of concerns for fluorinated organic compounds used in firefighting foams has been on perfluorinated compounds such as PFOS and PFOA, plus a range of *X:Y* fluorotelomers which each have various different effects in their own right, as well as being precursors for a number of other compounds due to partial degradation.

In addition to these commonly discussed compounds other variants of fluorinated organic compounds are of similar concern, regarded as having the same potential effects and producing similar breakdown and transformation products as the fluorotelomers and perfluorinated compounds [13,12,26,9,27] including:

- *X:Y:Z fluorotelomers* indicating X fully-fluorinated, Y singly-fluorinated carbons, and Z non-fluorinated carbon atoms prior to the first functional group (e.g. *9:1:2 fluorotelomer betaine*).
- *Fluoro-polymers* e.g. substituted in foam for fluorotelomers and perfluorinated compounds.
- *Substituted halogenated polyfluorocarbons* and perfluoropolyethers [28,29] (e.g. chlorinated polyfluorinated ether sulfonate, $C_8ClF_{16}O_4S^-$, which has similar characteristics, toxicity and behaviour to PFOS).

In regards to the use of fluoropolymers and their being considered in the same way as perfluorinated compounds and *X:Y* fluorotelomers, this is in line with the removal of the fluoropolymer exemption to the *Polymer Exemption Rule to Exclude Certain Perfluorinated Polymers* by U.S. EPA 2010 [30].

This exclusion refers to fluoropolymers containing, as an integral part of their composition, perfluoroalkyl moieties consisting of a CF_3- or longer chain length including perfluoroalkyl sulfonates (PFAS), perfluoroalkyl carboxylates (PFAC), fluorotelomers, or perfluoroalkyl moieties that are covalently bound to either a carbon or sulfur atom where the carbon or sulfur atom is an integral part of the polymer molecule. These fluoropolymers are now regarded as posing an unreasonable risk to human health or the environment.

While the simple fluorinated homopolymers such as PTFE (Teflon®) are not of concern, the more complex branched copolymers have the potential to have similar effects to *poly*-fluoroalkyl and *per*-fluoroalkyl compounds or partially degrade to compounds of concern.

2.2 Biochemical oxygen demand (BOD)

Biochemical oxygen demand is a measure of the amount of oxygen consumed, primarily by aerobic bacteria, in breaking down organic matter in a water body (with some contribution from algal respiration, sediment and chemical uptake). The terms *biochemical* oxygen demand and *biological* oxygen demand are interchangeable for the purposes of the Policy.

Notwithstanding that compounds used in the formulation of firefighting foams may have separate acute and chronic toxic effects, the primary concern regarding the BOD potential of firefighting foam is that elevated BOD associated with degradation of organic components, such as glycols or glycol ethers, will result in rapid depletion of dissolved oxygen in a water body causing harm to aquatic life, mainly through asphyxiation.

The majority of foams have high potential BOD values (expressed as BOD for the concentrate) generally in the higher range between 1,500 mg/L to 450,000 mg/L. Given that the natural dissolved oxygen concentrations in bodies of water are relatively low, in the range of 6 mg/L to 9 mg/L (Figure 2.2 A), this means that there is significant potential for environmental harm even from the release of firewater derived from finished foam at 1% to 6% dilutions, particularly in confined bodies of water with limited volume and turnover to dilute and disperse contaminants.

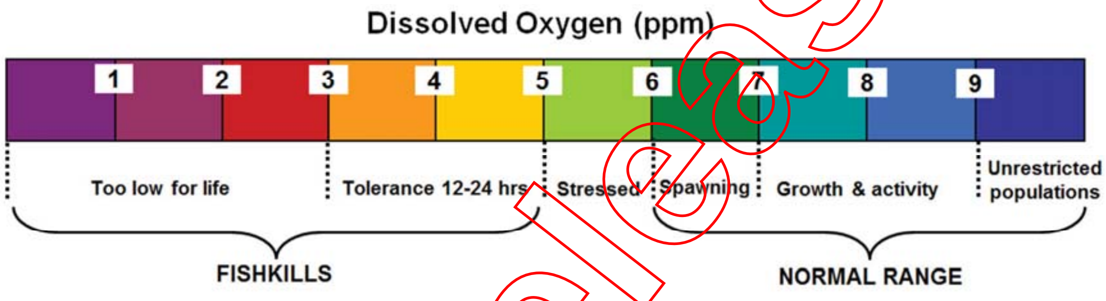


Figure 2.2 A – Dissolved oxygen effects on aquatic animals in water bodies
(Adapted from *Dissolved oxygen in water* – Water Research Center, Dallas, Pennsylvania)

From the foam user's perspective, as well as for the incident responder, when planning for responses it is highly desirable to put in place procedures and measures to contain and prevent or minimise the release of firewater (e.g. by containment in ponds, bunds or drains) for a sufficient period to allow degradation to occur before release such that the elevated BOD potential does not have any significant impacts on the adjacent bodies of water.

Usually the decomposition of the degradable organics introduced to a body of water can in many (but not all) cases be assumed to have proceeded to about 70% of the final value after 5 days (the BOD_5 value) [31] and is effectively complete after 20 to 28 days with no further significant BOD impacts likely [32,26].

While the BOD process in a body of water may be complete by about 28 days after the release, there may be a further lag while dissolved oxygen levels in the water return to normal, e.g. from additional BOD associated with dead vegetation present and/or a delay in return to a normal equilibrium for the biota in the waterway. Measurements of the recovery of dissolved oxygen levels back to normal concentrations in the water should be used to monitor progress.

When assessing the potential for BOD to affect dissolved oxygen levels in a body of water, say from SDS information, note that the standard BOD test is carried out at 20ºC, therefore biodegradation can be expected to proceed more rapidly at higher water temperatures and will be slower at temperatures below 20ºC.

Chemical oxygen demand (COD) is not the same as BOD, BOD is a subset of COD (Figure 2.2 B). Both COD and BOD values must be cited for foam concentrate. COD is a measure of the theoretical maximum amount of oxygen required to oxidise all of the oxidisable organics in a sample (clearly excluding persistent organic compounds not oxidisable by the method or oxidisable in the environment), the COD test is carried out under relatively strong oxidising conditions using acid dichromate. COD does not represent the degree of oxidation that will occur in the natural environment.

The ratio of BOD to COD represents the proportion of the organic components in a material that are readily biodegradable in the environment. At a minimum the values for COD, BOD$_5$ and BOD$_{28}$ should be cited in the SDS for foam concentrate to provide an indication of:

- immediate effects (≈BOD$_5$), i.e., acute oxygen stress
- overall oxygen demand (≈BOD$_{28}$ or BOD$_n$), i.e., a measure of the degradation burden
- overall biodegradability (BOD as a proportion of COD).

If the progressive natural degradation of the foam product is unusual then the SDS should cite a range of BOD values (e.g. 5, 10, 15, 20, 28 day) or the degradation BOD characteristics can be represented by a graph of BOD against a relevant time period of 28 days or more [32].

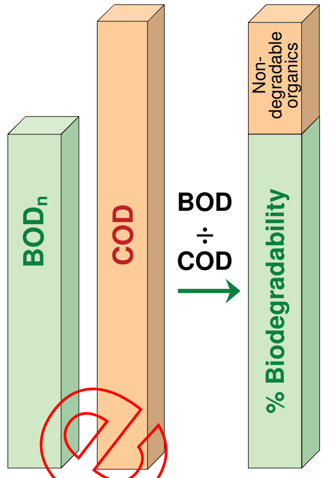


Figure 2.2 B
Relationship of BOD to COD

2.3 Biodegradability

In terms of the potential effects on the environment of a release of firefighting foam there needs to be consideration of the duration and severity of the effects of toxic compounds as well as the oxygen depleting BOD effects, which may be related to relatively non-toxic compounds.

Biodegradability is closely tied to BOD processes and describes the extent to which the organic components in a product will break down through natural processes in the environment and therefore the extent and duration of potential impacts of those compounds until they degrade.

The focus of biodegradability is mostly on the breakdown of the toxic components to non-toxic end-products such as salts, water and carbon dioxide, a process known as mineralisation. A large proportion of the compounds in firefighting foam are degradable organics such as glycol ether solvents and hydrocarbon surfactants which result in high overall biodegradability as judged from the ratio of BOD to COD (Figure 2.2 B). In many cases there is reliance on natural breakdown processes to break down toxic compounds and to remediate soils and water bodies over time.

The degradability of a product or waste under environmental or biological treatment conditions is generally determined as the ratio of the 28 day biochemical oxygen demand (BOD$_{28}$) to the total chemical oxygen demand (COD) of oxidisable organics, expressed as a percentage (BOD$_{28}$/COD x 100). However, this assumes that all the organic components are able to be oxidised in the standard COD method. In the case of fluorinated foams this does not take into account the non-degradable fluorinated organic compounds that cannot be readily oxidised as they are chemically extremely stable and resistant to oxidation by acid dichromate [26].

For the purposes of classifying and stating the biodegradability of a firefighting foam all the organic compounds in its composition must degrade under normal environmental conditions within 28 days from the time of its release to water by:

- >95% to be classed as *readily biodegradable*
- >99% to be classed as *fully biodegradable*.

Where some organic components eventually degrade, but are not readily or fully degradable within 28 days under environmental conditions, the period over which the organics degrade needs to be stated (e.g. "*95% biodegradable over 45 days*").

Where the foam contains persistent toxic organic compounds it cannot be described or implied as being readily or fully biodegradable even when the overall persistent organic compounds are <5% w/v in the concentrate or <1% w/w of the total organic components respectively.

Rapid and complete biodegradability is desirable for pollutants released to the environment even if the BOD is high and their acute toxicity is higher than less acutely-toxic but persistent alternatives.

2.4 Acute (short-term) toxicity

Acute toxicity refers to the immediate or short-term effects of contaminants; usually the effects occur within hours or days of exposure. Acute toxicity testing observes the effects of a contaminant over a short period, e.g. over 24 hours, relative to a single exposure at the beginning of the test procedure or the effects of exposure to particular concentrations [33].

Concerns regarding acute toxicity of foam releases focus on the potential to cause harm to aquatic organisms in bodies of water. Tests for acute toxicity usually involve aquatic test species such as crustaceans, algae and fish relevant to the location or at least tests that use standardised test species across the relevant groups.

The foam management Policy stipulates the standard test methodologies and information that must be made available so that users, regulators and incident responders have a basis for assessing the acute toxicity risks they face and make appropriate comparisons, decisions and choices. The Policy includes guidance on relevant test species and best-practice test methods. It should be noted that sensitivity to toxins is variable across species and assumptions cannot be made even within related groups such as fish and crustaceans [34,35].

Significant problems have arisen for foam users, environmental regulators and incident responders in that acute ecological toxicity test data and information reported in foam product information and safety data sheets are rarely adequate, or are even completely absent, making it difficult or impossible for the user to make an informed judgement or decision in regard to a balanced environmental risk assessment for response planning or incident management.

Quite often acute ecological toxicity information cited in the SDS and product information only relates to selected components of the foam and is not for the final product formulation. It is well recognised that the overall toxicity of mixtures may be very different from its separate ingredients [36,37] through largely unpredictable synergistic effects between components. For acute toxicity test results to be relevant the tests must be done for the final product formulation and at the usage concentration, it is not sufficient, and is very often misleading, only to report on selected components in isolation.

Manufacturers/suppliers may choose to provide additional information in SDS and product technical information beyond that required by the Policy. Equally, users may need to seek further information relevant to particular or unusual circumstances that they face or for the environment in which the foam will be used (such as the near-shore marine environment) before deciding how best to address their needs and obligations.

2.5 Persistence

The presence of any persistent toxic compounds in releases to the environment is of concern. Toxicity effects on health and the environment can be exerted over a long period with the added possibility that bioaccumulation and long-range dispersal may occur [38,39,40,41,8]. The term *persistence* in the Policy is used to mean environmental persistence; it should not be confused with bio-persistence (see Section 2.8).

Firefighting foams are often used in situations where containment may be difficult, so it is likely that there will be releases to the environment and dispersal under a variety of circumstances. This could occur on a large or small scale during incidents and normal operational activities. Where persistent toxic compounds are present, care must be taken to ensure that the likely environmental risks and impacts are *fully understood* and such products are only used with appropriate containment and controls in place.

Many pollutants released to the environment can be expected to naturally degrade over time or to become immobilised, (e.g. by adsorption to sediments, microbial degradation, oxidation, reduction, hydrolysis, UV photo-degradation, hydroxyl attack in the atmosphere, etc.). However, fluorinated organic compounds do not naturally diminish in this way as might normally be expected due to their extreme persistence, solubility, high mobility, high acid strength (low pKa) and dispersibility of volatile precursors or breakdown products in air (such as FTOHs or short-chain perfluoroalkyl derivatives from landfill or WWTP emissions), in water and in soil [42,43,9,44,45,14].

Extreme persistence in itself is not a primary problematic characteristic but when the compounds or their degradation products are also toxic, highly dispersible, and may be biopersistent and bioaccumulative, even compounds that have short-term low to moderate toxicity require very close scrutiny for the potential for adverse health and environmental effects to occur over the longer term and make a conservative approach to management necessary, i.e. the application of *the precautionary principle* [26,3]. Environmental persistence increases the risks of toxicity, biopersistence, bioaccumulation, bioconcentration and biomagnification occurring.

An organic compound is considered environmentally *persistent* (*P*) or *very persistent* (*vP*) under *Annex XIII of REACH (EC 2011)* when its half-life, including that of its degradation products with similar characteristics or effects, is greater than those shown in Table 2.5 A for each environmental compartment.

Table 2.5 A – Criteria for identifying Persistent (P) and Very Persistent (vP) substances [46]

Persistent (P) degradation half-life		**Very Persistent (vP) degradation half-life**	
Marine water	>60 days	Marine water	>60 days
Fresh or estuarine water	>40 days	Fresh, or estuarine water	>60 days
Marine sediment	>180 days	Marine sediment	>180 days
Fresh or estuarine sediment	>120 days	Fresh, or estuarine sediment	>180 days
Soil	>120 days	Soil	>180 days.

2.5.1 Persistence of fluorinated organic compounds

Many firefighting foams are heavily reliant on longer-chain (>C6) fluorinated organic compounds for their firefighting performance and these foams have been extremely effective in a range of firefighting applications with few alternatives available until recently.

Since about 2000 there has been growing and significant evidence of the adverse health and environmental effects of poly- and per-fluorinated organic compounds released from various sources including fabric protectants and manufacturing processes as well as firefighting foams. Perfluorinated organic compounds are well known to be extremely persistent in the environment, with no known natural processes whereby they will degrade [22,11,6,42,47,8].

The extreme persistence of perfluorinated organic compounds can be described as “geological” to the extent that rock strata in the distant future, formed from current contaminated sediments, are likely to contain un-degraded perfluorinated organic compounds from releases in the last few decades as complete mineralization is not expected to occur under natural conditions [48,49]. In addition, fluorinated organic compounds are also likely to be still circulating in the environment after similar very long periods of time. For example, the simplest perfluoroalkyl compound, fluoro-methane (CF_4), has an estimated half-life in the upper atmosphere of >50,000 years [50].

The carbon-fluorine bond in fluorinated organic compounds is extremely strong and stable, it is the strongest bond in organic chemistry [7,9,51,52], enhanced by overlapping electron shells and a short C-F bond length [45]. This gives extreme durability to perfluorinated organic compounds under all but exceptional chemical and physical conditions. It is not surprising that perfluorinated organic compounds do not undergo biotic or abiotic degradation under environmental conditions given that even thermal degradation only occurs at temperatures of about 1,100ºC with at least 2 seconds residence time at that temperature [53,24,54,55].

Normally persistence or degradation in the environment is described in terms of a compound’s *half-life*, being the time it takes for 50% of the original amount or concentration of the compound to degrade. The environmental half-life of PFOA has been described as “*challenging or even* *impossible to measure*" with an estimate of PFOA's half-life under artificial hydrolysis conditions in the laboratory of about 92 years [22]. Even under these artificial conditions the expected degradation of PFOA to a residual amount below 1% of the original concentration would be seven half-lives or about 644 years.

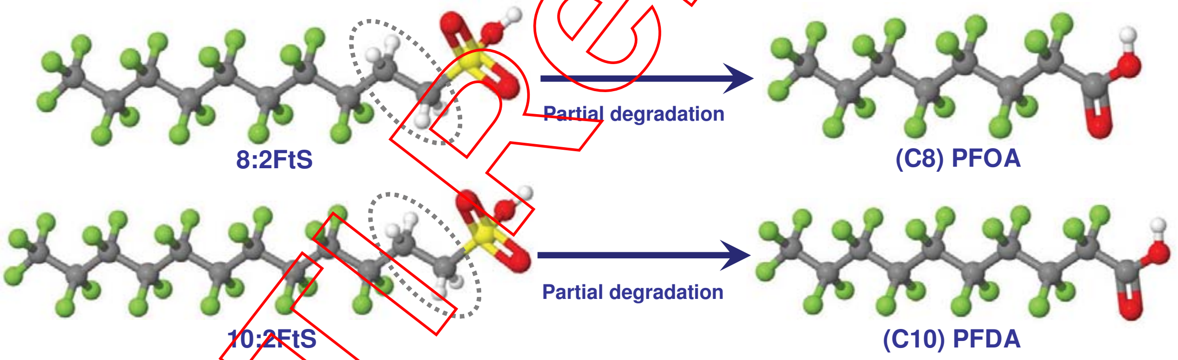
Another estimate puts the half-life of PFOA under hydrolysis at about 235 years [41] giving an expected time to degradation below 1% of about 1,645 years. These estimates are purely notional as PFOA persistence, and that of all similar perfluorinated organic compounds, is expected to be effectively indefinite under environmental conditions.

2.5.2 Precursors and partial degradation of fluorinated organic compounds

While *per*fluorinated compounds will not degrade under environmental conditions, fluorotelomers such as 8:2 FtS have part of the carbon chain (the dimethylene group) that is not fully fluorinated and on release to the environment will *partially degrade,* however their end-point degradation products are still highly persistent perfluorinated compounds related to the fully fluorinated part of the carbon chain (Figure 2.5.1 A) [21,25], for example:

- In the case of a variety of 8:2 fluorotelomers the end point is the carboxylic acid PFOA, after the non-fluorinated -CH_2-CH_2- dimethylene group is lost.
- For higher homologue 10:2 fluorotelomers the end point is perfluorodecanoic acid (PFDA).
- For compounds such as perflourooctyl sulfonamides the partial degradation end-point is likely to be PFOS.

From an environmental standpoint it is highly misleading to describe fluorinated organic compounds as "*degradable*" which implies in general parlance to the non-specialist end-user that the product *fully* degrades and therefore it might be assumed that there are no residual persistent end-compounds of concern. This is not the case.



Atoms–Green=Fluorine, Grey=Carbon, White=Hydrogen, Yellow=Sulphur, Red=Oxygen, non-fluorinated carbon atoms circled

Figure 2.5.1 A – Degradation of 8:2 and 10:2 fluorotelomer compounds to PFOA and PFDA (The sulfonic acid –HSO_3 functional group shown in the example *X:Y* compounds is notional. A range of other functional groups can occur instead such as betaine, sulfonamide amine, etc. with the same degradation end-points of PFOA and PFDA). (Molecule graphics generated by www.chemspider.com).

The "*degradation*" of fluorinated organic compounds under environmental conditions only refers to the *partial degradation* or loss of the non-fluorinated carbons (usually a C2 dimethylene group) from some compounds and also, under specific conditions, limited partial de-fluorination adjacent to non-fluorinated carbon atoms, ultimately (and possibly through intermediate steps) leaving behind a persistent *per*-fluorinated compound. This process may also involve a transformation where the functional group changes, e.g. a sulfonamide is replaced by a sulfonate.

The eventual end-point compound left behind by partial degradation is a highly persistent p*er*-fluorinated compound which does not degrade under environmental conditions [56,47,45]. The partial degradation/transformation steps and their intermediate compounds (and their half-lives) that lead to the eventual end-point compound, and the environmental behaviour of each of these compounds, are also not well understood. This applies to both long-chain and short chain compounds [15,27,47].

Foams containing significant concentrations of PFOA precursor compounds such as 8:2 fluorotelomers effectively leave the user unwittingly exposed to the liability of having released foam that relatively quickly generates PFOA with a very significant potential to cause health and environmental impacts.

Similarly, those foams with significant concentrations of longer-chain fluorotelomers, such as 10:2FtS and 12:2FtS or equivalents ([13,25] and Tables 2.1 A & B), will partially degrade to C10 perfluorodecanoate (PFDA) and C12 perfluorododecanoate respectively. These are higher homologues of PFOA which are orders of magnitude more toxic and more bioaccumulative [40].

Given the relatively rapid degradation of 8:2 fluoroteleomers to PFOA in the environment the release of foam that contains these PFOA precursor compounds is effectively regarded as a release of PFOA to the environment as the PFOA precursor compounds can have relatively short half-lives (e.g. as short as 10.3 days for 8:2 fluorotelomer stearate monoester [57]). Similarly perfluorooctyl sulfonamido amine in a foam is likely to degrade to PFOS amongst at least 96 other PFOS precursor substances [45].

Effectively some foams advertised as "*PFOA and PFOS free*" may not remain PFOS or PFOA-free for very long once put into use and partial degradation occurs.

Under the Policy foams containing PFOA and/or its precursors and their higher homologues are required to be withdrawn from service as soon as it is practicable and disposed of properly. It is recognised that a significant number of firefighting foams in service are currently dependent upon PFOA precursor fluorinated organic compounds (as well as very significant levels of the more toxic longer-chain C10 and C12 compounds [13,16]) and that a reasonable time to transition to alternative foams will be required; this will vary according to the complexity of the particular circumstances.

Firefighting foams that contain significant levels of PFOS (>10 mg/kg), its higher homologues and their precursors are of ***very significant concern*** for human health and the environment and as such the Policy requires that they are not to be used and must be withdrawn from service ***immediately***, secured and arrangements made for proper disposal [53,58]. The potential for adverse health and environmental effects by PFOS has been well understood for some considerable time.

2.6 Bioaccumulation

Bioaccumulation is the general and continued uptake of substances from the environment through contact, with nutrient uptake and through diet resulting in an increasing concentration within the organism which increases the potential for health and environmental harm to occur substantially, especially in the case of toxic, highly persistent compounds that are not metabolised or are slow to be eliminated from animals.

In a general sense the term bioaccumulation also encompasses the related terms of bioconcentration (where uptake exceeds elimination), and biomagnification (increased concentration via uptake from the food chain) (see Policy Definitions).

The persistence of any compound in the environment increases the chances of it bioaccumulating (as well as bioconcentrating and biomaginifying), especially if the compound has an affinity for a particular compartment in biological systems, e.g. it associates with fats, proteins or a particular organ [38,39,59,7]. Given that firefighting foams can be released to the environment under various circumstances, care must be taken to ensure that the behaviour of any potentially bioaccumulative compounds are well understood, especially those that are toxic and persistent.

Various long-chain fluorinated organic compounds are known to bioaccumulate and have been detected world-wide in various organisms [60,38,61]. Uptake of PFOS and PFOA is known to occur for plants growing in contaminated soils and has also been found in food products including fish, meat and milk products [42].

Testing with aquatic species suggests that PFOA is "*not highly bioaccumulative*", however it should be taken into account that PFOA is highly soluble plus aquatic species used in standard tests have an additional mode of elimination via the large surface area of their gills that terrestrial animals do not have. That is to say, the gills are an added way that aquatic animals can more readily excrete contaminants from their bodies back into the water so tests using aquatic species should be viewed with caution in respect to their applicability to species without gills.

PFOA is also only one of a wide diversity of compounds that are used, occur in or are derived from foam, with very little being known about their behaviour in the environment [13,9,12]. Some compounds can persist for years to decades [62,63] before partially breaking down to end-point compounds such as PFOA and PFHxA.

It is worth noting that standard assessments of bioaccumulation potential using the N-octanol-water partitioning coefficient (K_{ow}) is not valid for surface active substances (surfactants) including fluorosurfactants as they do not tend to accumulate in storage lipids but rather associate with proteins and concentrate primarily in the blood and liver among other tissues [64,40,59,60,39].

Assessment of the bioaccumulative potential of substances against existing regulatory criteria for bioconcentration factors (BCFs) and bioaccumulation factors (BAFs), such as those developed under CEPA 1999, need to be applied cautiously and take into account that these threshold criteria may not be applicable as they are based on historical experience with neutral, non-metabolised organic substances in freshwater aquatic systems, with particular reference to lipophilic substances [41,11,59] which, unlike fluorinated organics, primarily partition into fats.

Fluorinated organic substances depart in their characteristics and behaviour from the traditional assumptions made regarding BCFs and BAFs in a number of significant respects, as well as there being indications of bioaccumulation occurring in a number of terrestrial and marine animals [65,41,38,20].

The unusual nature and behaviour of persistent toxic organic compounds, including per- and poly-fluorinated organics, strongly suggests that a conservative approach to management must be taken given that many show indications that they or their breakdown products may be bioaccumulative. For example, in earthworms (a primary trophic group) exposure to PFOS, PFOA and 6:2FtS gave similar bioaccumulation factors for PFOS (2.6) and 6:2FtS (2.4) suggesting undegraded 6:2FtS bioaccumulates to a similar extent as PFOS and PFOA [65].

2.7 Chronic (long-term) toxicity

Many comparisons have been made between the toxicity of fluorinated and fluorine-free foams. However, such comparisons are almost always in regards to short-term acute toxicity with rarely any mention of long-term chronic toxicity. When considering the potential adverse effects of toxicity the short-term toxicity characteristics of a product is only one aspect that should be considered and is not directly relatable to long-term toxicity.

Short-term toxicity is the most often cited characteristic in foam product information and SDS, it is misleading to assess and compare the potential effects of foams on this basis alone, especially when some products may contain persistent and bioaccumulative compounds with subtle, but nonetheless, toxic long-term effects in their formulation.

The long-term, chronic toxicity must also be considered in the light of how persistent the contaminants are in the environment, how they may be converted to other compounds and how they behave in biological systems. For persistent pollutants, such as fluorinated organic compounds, the degree of persistence is a very significant consideration in assessing the chronic toxicity risk posed to human health and the environment [66,33,61].

Put simply, persistent pollutants, even if they have relatively low acute or immediate toxicity effects, have a very long time over which they can exert their effects, especially if there are any indications that bioaccumulation, bioconcentration and/or biomagnification could also occur or if there is slow elimination from the body [67,39,41].

2.8 PBT (Persistence-Bioaccumulation-Toxicity)

The overall potential for a firefighting foam to cause adverse environmental effects needs to be assessed in terms of its Persistence-Bioaccumulation-Toxicity (PBT) profile. This needs to take into account both the short-term and long-term impacts of the final formulation. Each component needs to be weighted appropriately in arriving at the overall evaluation.

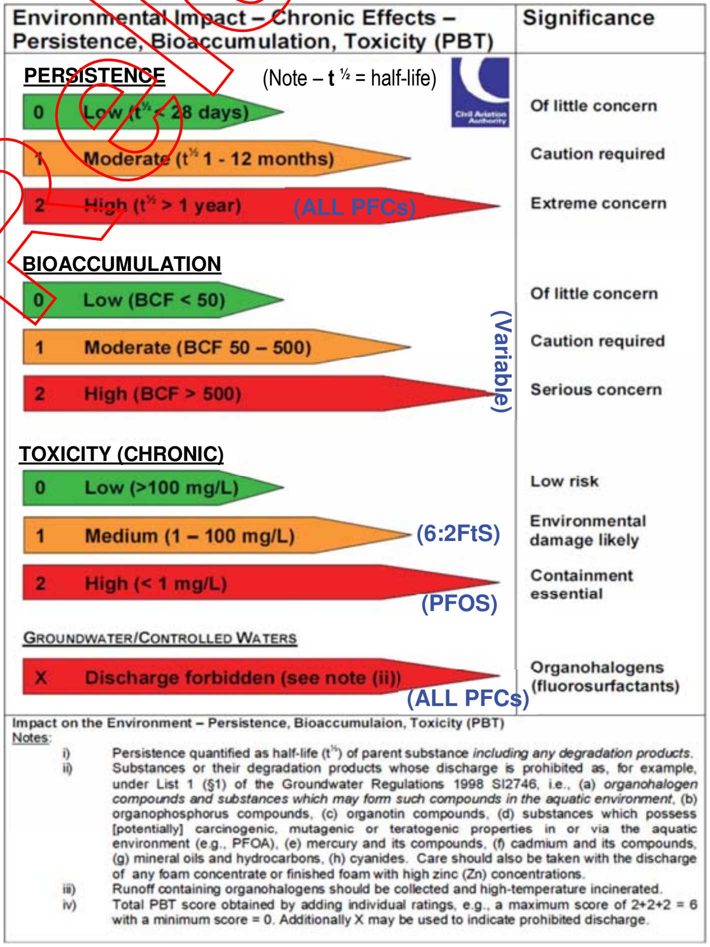
Where there is insufficient information on a particular foam formulation, or the principle components of concern, a conservative approach to PBT assessment and product management needs to be taken in line with the *precautionary principle*. This is especially the case where there are compounds in use for which there are indications that long-term effects may be expressed through biopersistence, bioaccumulation, bioconcentration or biomagnification or where there is the potential for long-range transport and there are known occurrences of contaminants in biota that are very unlikely to be the result of direct exposure [20,41,68].

The general *persistence* of a compound refers to its overall persistence in the environment subject to degrading influences such as photolysis, oxidation, hydrolysis and biodegradation. The more specific terms *bio-persistence, bio-accumulation, bio-concentration* and *bio-magnification* refer to biotic processes within or involving living organisms.

The term *biopersistence* has been frequently misused in general publications and marketing information e.g. "*biopersistence in the environment*" has been used incorrectly where *environmental persistence* is more accurate and appropriate. *Biopersistence* specifically refers to how long a compound, once taken up by the organism, persists in the body of the organism. This largely depends on the rate that it is cleared or eliminated [26,33] e.g. by respiration, excretion or metabolism (*bioelimination*). Bioelimination rates and mechanisms vary widely between organisms and may also be subject to sex-specific hormonally controlled differences within species.

When assessing the potential for adverse effects by bioaccumulation of the components of a complex mixture such as a foam concentrate factors that need to be taken into account include:

- Particular compounds that may bioaccumulate or are similar to those that are known to.
- Breakdown products or metabolites if they are similar substances or have similar effects.
- Solvents and detergents present in formulations that affect cellular uptake and metabolism.



Environmental Impact – Chronic Effects – Persistence, Bioaccumulation, Toxicity (PBT)	Significance
PERSISTENCE (Note – t ½ = half-life)	
0 Low ($t^{½}$ < 28 days)	Of little concern
1 Moderate ($t^{½}$ 1 - 12 months)	Caution required
2 High ($t^{½}$ > 1 year) (ALL PFCs)	Extreme concern
BIOACCUMULATION	
0 Low (BCF < 50)	Of little concern
1 Moderate (BCF 50 – 500)	Caution required
2 High (BCF > 500) (Variable)	Serious concern
TOXICITY (CHRONIC)	
0 Low (>100 mg/L)	Low risk
1 Medium (1 – 100 mg/L) (6:2FtS)	Environmental damage likely
2 High (< 1 mg/L) (PFOS)	Containment essential
GROUNDWATER/CONTROLLED WATERS	
X Discharge forbidden (see note (ii)) (ALL PFCs)	Organohalogens (fluorosurfactants)

Impact on the Environment – Persistence, Bioaccumulaion, Toxicity (PBT)
Notes:

i) Persistence quantified as half-life ($t^{½}$) of parent substance *including any degradation products*.
ii) Substances or their degradation products whose discharge is prohibited as, for example, under List 1 (§1) of the Groundwater Regulations 1998 SI2746, i.e., (a) *organohalogen compounds and substances which may form such compounds in the aquatic environment*, (b) organophosphorus compounds, (c) organotin compounds, (d) substances which possess [potentially] carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment (e.g., PFOA), (e) mercury and its compounds, (f) cadmium and its compounds, (g) mineral oils and hydrocarbons, (h) cyanides. Care should also be taken with the discharge of any foam concentrate or finished foam with high zinc (Zn) concentrations.
iii) Runoff containing organohalogens should be collected and high-temperature incinerated.
iv) Total PBT score obtained by adding individual ratings, e.g., a maximum score of 2+2+2 = 6 with a minimum score = 0. Additionally X may be used to indicate prohibited discharge.

Figure 2.8 A – PBT simplified assessment [26]

While it is important to assess the effects of the combined formulation of any product, for practical purposes an initial assessment of bioaccumulation potential can be focussed on the compounds most likely to be involved (and their breakdown products) that are significantly environmentally persistent. That is, all those compounds that persist long enough to bioaccumulate and could exert adverse effects on health and/or the environment. This might include fluorotelomers, fluoropolymers, siloxanes [69], metal ligands or similar compounds and their breakdown products.

Given that the formulations of firefighting foams are by commercial necessity trade secrets, this puts the onus on the manufacturers to review the compounds in their formulations, including all possible breakdown products, and provide the relevant information to the user even if the compounds are only identified in a generic way in SDS and product information, e.g. "*Contains fluorinated organic compounds known to persist in the environment and are suspected to bioaccumulate in living organisms – Do not discharge to the environment*".

The octanol-water partition coefficient $\log(P_{ow})$ can in some cases be used to estimate the bioconcentration factor of a compound but this is not appropriate for surfactants [40,59] so a more direct measure of the bio-concentration factor (BCF) will need to be done [26].

In general, the potential for bioaccumulation (and bio-magnification) should be assumed as many poly- and perfluorinated organic compounds belong *to a class of substances known to have a potential to accumulate in living organisms*, *there are indications from structural features and there is no mitigating property such as hydrolysis (half-life less than 12 hours)* [70]. Individual BCFs for aquatic organisms are in any case only part of the overall trophic bio-magnification that can occur in food-chain, especially in higher predators [26].

The PBT profiling system proposed by the Civil Aviation Authority (Figure 2.8 A) provides a sound basis for a simplified PBT assessment in keeping with the precautionary principle mentioned elsewhere in these *Explanatory Notes*. For complex products this may need to be informed by a more detailed risk assessment similar to the Hazard Index method [37].

2.9 Health, safety, amenity and economic considerations

While the Management of Firefighting Foam Policy focusses primarily on the actual and potential impacts of firefighting foam on environmental values, questions have arisen regarding the potential health impacts of releases on the public, workers, firefighters and other responders as well as the broader effects on public amenity values, reputation, economic resources and costs to industry.

Since their first development and use fluorinated organic compounds are now found widely in the environment, plants, animals and the human population [5,41,71]. All foams contain a mix of various compounds in their formulations, often unique in the combination for each foam.

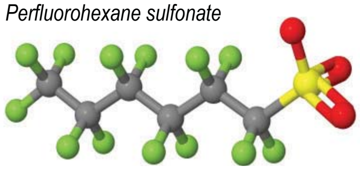
Common environmental effects of all foams are varying degrees of detergent toxicity and elevated biochemical oxygen demand that can have immediate adverse effects on biota in the aquatic environment. Further to that, some foams may contain compounds that can have long-term effects on worker health, public health, the environment and other values. Of particular concern are toxic compounds that are persistent, bioaccumulative and with long elimination times from animal species including the human body [72,73,39,67,62].

There is very significant evidence for adverse effects in mammals for many classes of fluorinated organic compounds and indications of similar problems for most others. The elimination half-lives for a range of fluorinated organic sulfonate and carboxylate compounds are variable across different mammals but are particularly long in humans [38,73,39,67,8,74] with elimination half-lives ranging from 1.5 years to 21.7 years (Table 2.9 A).

In the context of a person receiving a significant dose of PFOS (C8 compound) or PFHxS (notionally a C6 short-chain PFC, but behaving like a long-chain PFC), a number of half-lives may be required to reduce the concentration of the compound in their body to acceptable levels below which acute or chronic effects could occur; this may amount to a period of several decades.

This emphasises that it is all the more important the need to prevent significant exposure by responders and the public in the first place.

Table 2.9 A – Elimination half-lives in humans of PFHxA, PFOA and PFOS

Compound	Half life	
C6, PFHxS	8.5 years (2.2 to 27 years)	*Perfluorohexane sulfonate* 
C8, PFOA	3.8 years (1.5 to 9.1 years)	
C8, PFOS	5.4 years (2.4 to 21.7 years)	
(PFHxS – Perfluorohexane sulfonate, $C_6F_{13}O_3S$, structure at right)		

2.9.1 The costs of incidents involving firefighting foam

Generally the focus on risk management for firefighting is on the immediate priorities of rapid and effective suppression or extinguishment of fire. In addition to this there needs to be consideration of the practicalities and costs of the recovery phase. Wherever possible there should be pre-planning that seeks to minimise the unnecessary costs and impacts of the incident response.

Incidents often generate very large quantities of contaminated soil and firewater, and the cost of treatment can be significant under some circumstances and the damage to adjacent values beyond the site also being considerable. There are very limited options for treatment of wastewater and soils contaminated with persistent contaminants and most are expensive as materials have to be transported to treatment facilities and subjected to high temperature destruction methods such as incineration in a cement kiln [54,75,76,55,53,14] or subjected to chemical immobilisation.

The determination of overall risk is based on *Probability* X *Consequence (AS/NZS 31000:2009 Risk Management–Principles and guidelines)*. While the probability of a large-scale incident resulting in a significant release is relatively low, the lasting consequences when it does occur can be catastrophic with few options available during the emergency to control or prevent releases beyond the site that could result in impacts.

For example, the 2005 fire at the relatively small Buncefield bulk hydrocarbon storage facility in the UK necessitated the use of about 750,000 litres of fluorinated foam concentrate during the response. The incident generated about 55 million litres of firewater, most of which was released to the environment (just 16ML was recovered) with groundwater drinking water supplies for north London also compromised [77].

At Coode Island in Melbourne in 1991 about 200 tonnes of firefighting foam concentrate were used [78] on a dock-side hydrocarbon chemical storage facility fire and most of the firewater was released to the adjacent waterway. The foam used was probably 3M Light Water AFFF. Based on the two most likely formulations the release of fluorinated organic compounds is likely to have been very substantial at between 3 tonnes and 30 tonnes (Table 2.9.1 A).

This represents a release during the Coode Island fire of up to about 30,000 kilograms of fluorinated organic compounds about a third of which was PFOS [15]. The potential for significant effects on the environment, health of responders and the public from the perspective of the foam chemicals released was not recognised at the time and was not investigated.

Table 2.9.1 A – Coode Island fire, FOCs released based on 200 tonnes of concentrate used

Foam type	3M Light Water FC-203 CE (1991)	3M Light Water FC-203 FC
Composition from MSDS	*alkyl sulfate salts... 5%,* *amphoteric fluoroalkylamide derivatives... 5%,* *perfluoroalkly sulfonate salts... 5%*	*amphoteric fluoroalkylamide 1–5%,* *residual fluorochemicals <1%,* *PFOS salts 0.5-1.5%*
Fluorinated organic compounds	30,000 kg (PFOS 10,000 kg)	3,000 kg to 15,000 kg (PFOS 1,000 kg to 3,000 kg)

Any large-scale release would be on top of and exacerbate the existing chronic low-level but nonetheless cumulative releases to waterways from domestic sources, such as carpet and fabric cleaning, inappropriate fluorinated waste disposal, and leaching of contaminated soils.

Investigations of the longer-term fate of relatively small releases and spills of perfluorinated organic compounds, (Toronto 2000, 330-1,650 kg PFCs [63,79] and Amsterdam 2008, ~572 kg PFCs [80]), have found elevated levels of fluorinated organic compounds persisting for at least 15 years in the aquatic environment, especially in sediments and fish [8] highlighting the potential for spills to have longer-term effects on environmental and fisheries values with a significant health risk posed to the public consuming seafood.

Exposure concerns are not just limited to PFOS, PFOA and higher homologues but also concern the shorter-chain compounds such as PFHxS (perfluorohexane sulfonate) that have been found in humans and associated with consumption of contaminated drinking water and fish [8,74]. PFHxS is present in, or results from some current and proposed alternative "*C6 or 6:2 fluorotelomer-based*" firefighting foams, as well as from legacy PFOS foams as it is a homologue of PFOS present as a contaminant.

A large-scale release of contaminated firewater from a large hydrocarbon storage facility incident, a hydrocarbon shipping tanker fire or even cumulative smaller releases to waterways and the marine environment would potentially impact those values not only by direct contamination of seafood resources and aquaculture stocks but also by generating the *perception* of contamination which is very likely to severely affect public opinion and local and overseas market purchases of local seafood produce.

For example, Queensland hosts commercial fisheries to the *annual value* about $436 million with aquaculture valued at $103 million and recreational fisheries valued at about $73 million [81]. In Moreton Bay alone, adjacent to Brisbane, the value of commercial and recreational fisheries to Queensland's economy is between $44 million and $54 million per year [82].

Various marine oil spills and port dredging activities over the last decade, involving less persistent, and even undefined contaminants, compared to those associated with some firefighting foams, are examples where strong public and industry concerns have been expressed regarding pollution impacts on economic, amenity, cultural and recreational values [83,84].

If the pollution included indefinitely persistent and well recognised pollutants, such as fluorinated organic compounds, the damage to that industry, and to the recreational fishing sector and the state's reputation through actual or perceived contamination, might then extend for years to decades raising issues of who would be responsible for compensation for that period.

Where a large-scale incident involved non-persistent, biodegradable contaminants including organohalogen-free foam and hydrocarbons the extent of damage would be limited to largely acceptable short-term acute impacts from which the environment and resource values would recover with no risk of long-term harm or the perception of persistent pollution.

2.9.2 Human health and safety implications

While the very valid issues of responder and firefighter safety are recognised as a high priority in assessing the effectiveness of firefighting foam to provide protection against immediate threats during incidents the long-term health and safety aspects of exposure by users also need to be seriously considered as well.

Subject to type, concentration, duration and frequency of exposure, some foam chemicals may represent a significant health risk for users who do not take appropriate personal protective measures such as wearing of respiratory protection against inhalation and ingestion of contaminants in aerosols [85]. For example, fine, easily dispersed and inhaled aerosol particles are well known to be produced by bursting bubbles. Oral (and by inference respiratory) PFOS and PFOA exposures are readily absorbed (90%) and distributed through the body in blood serum. Excretion pathways, such as in bile, can be confounded by reabsorption, such as in the gastrointestinal tract [8].

Various fluorinated organic compounds are present in the blood of the general human population of which PFOA and PFOS are the most frequently detected compounds and of significant concern for human health [48,86,74]. However, the prominence of PFOS and PFOA as research subjects may be a biased perception as other less well-known compounds have not been as widely researched and reported and probably many more remain to be unidentified [17,15]. PFOA and PFOS both have long residence times in human blood of more than 1,000 days [60] and other compounds may behave similarly. None of these fluorochemicals were detectable as organic fluorine in reference databank human serum samples taken before fluorochemicals were manufactured and used commercially shortly after World War II [87].

High levels of PFOS and PFOA are toxic for reproduction and development of the foetus and are potentially carcinogenic in animal tests [8]. In addition, 8:2 fluorotelomer phosphate diesters, 8:2 fluorotelomer alcohols, and PFOA show endocrine effects in different *in-vitro* and *in-vivo* tests. PFOA and PFOS are also associated with reduced humoral immune response in early childhood immunizations [60,8].

Probable associations have been found between exposure to PFOA, PFOS and other fluorinated organic compounds and health effects in humans including hyperuricemia, high cholesterol (hypercholesteremia), ulcerative colitis, thyroid diseases, testicular cancer, delayed puberty, asthma, kidney cancer, liver damage, preeclampsia, ADHD (attention deficit hyperactivity disorder), endocrine disruption and elevated blood pressure during pregnancy [60,67,8,73,88,74].

For occupationally exposed users the clear correlations with possible adverse health effects, biotransformation in the body, long body-residence times and lack of definitive information on the behaviour and un-researched effects of the diversity of (largely unknown) compounds and combinations mean that special care needs to be taken to prevent exposure to fluorinated organic compounds as part of day-to-day operations as well as during incidents where responders or workers unfamiliar with the issue may be unwittingly exposed.

Significant occupational exposure to foam chemicals can occur unwittingly during incidents, training, testing and clean-up [119].

For example, ingestion and inhalation of aerosols created by sprays, wind, heated vapours and bursting bubbles can result in direct contaminant intake including foam chemicals.

3 Treatment and disposal of wastes

Firewater that contains firefighting foam requires appropriate treatment and disposal based on its composition. The comments below refer to treatment and disposal firewater or wastewater that only contains firefighting foam. Any firewater or wastewater that contains other contaminants such as hydrocarbons, chemicals or products of combustion from a spill or incident needs to be considered in terms of the particular combination of contaminants as well as the firefighting foam content.

All solid and liquid wastes that contain fluorinated organic compounds (e.g. concentrates, firewater, wash-water, run-off, soils, absorbents, etc.) are regarded as regulated wastes and must only be disposed of through a facility that is licensed to take regulated wastes.

3.1 Firewater and wastewater treatment

Firefighting foams that are fully biodegradable can be treated and disposed of by wastewater treatment such as on-site treatment plant, degradation in holding ponds, irrigation to suitable land for degradation or by discharge to sewer for treatment at a municipal sewage treatment plant.

Appropriate consideration must be given to what site and system/method are to be used for treatment and/or disposal of fully biodegradable foam and that it is appropriate for that purpose and does not have a potential for releases that might cause environmental harm.

Discharges of foam, firewater or wastewater to sewer for treatment and disposal must be by permit or agreement with the authority accepting the discharge of the waste to sewer for treatment. Firefighting foams, wastewater or firewater containing significant levels of fluorinated organic compounds (see *Policy Section 6.4.2*) or similar persistent toxic compounds cannot be treated or removed by standard wastewater treatment processes but must not be discharged to sewer, it must be disposed of to a facility approved to treat such wastes. Fluorinated organic compounds are not captured by standard wastewater treatment processes [89,61,62].

Foams that contain any persistent toxic compounds, including fluorinated organic compounds, are not regarded as fully biodegradable for the purposes of the Policy and special consideration needs to be given to the potential for impacts associated with treatment and disposal of any persistent toxic compounds.

For firefighting foam containing persistent compounds such as fluorinated organic compounds the wastewater must be fully contained and not released to waterways or other bodies of water, stormwater, soils, groundwater or to sewer.

Municipal sewage treatment plants are not capable of treating or capturing fluorinated organic compounds such as PFOS, PFOA or the shorter-chain substitutes such as 6:2FtS [24,89,61,6] with the result that the fluorinated organic compounds are released to water bodies or land in their discharges as well as contaminating the sewage sludge or biosolids fraction that are subsequently sent to landfill or distributed for soil improvement i.e., agricultural “top dressing”, leading to further leaching and release to the environment [42].

Waste managers accepting fluorinated organic compounds as concentrates, firewater, wastewater or in other wastes must ensure that they are fully contained and properly disposed of in such a way so as to completely immobilise or destroy them. Established methods for destruction include dedicated high temperature thermal incineration or in a cement kiln [54,75,76,55] where the fluorine component is ultimately captured by scrubbing of the flue gasses to remove hydrogen fluoride (HF) or immobilised in the cement matrix as inert and environmentally neutral calcium fluoride (CaF). Other forms of high temperature destruction such as in a plasma-arc furnace are equally effective. Such waste disposal facilities would need to be specifically licensed and appropriate conditions imposed for this type of activity in most jurisdictions.

Fixation of contaminated soils and solid materials with an appropriate immobilisation reagent may be feasible to the point where the wastes can be disposed of to a licensed landfill. Criteria to define what levels of contamination would require treatment and what levels of immobilisation/leachability for landfilling [90] would be acceptable are under consideration. Landfills (and WWTP) have been shown to be sources of small volatile fluorinated species capable of diffusing into the upper atmosphere with presumed global warming potential (GWP).

3.2 Foam concentrate disposal

Firefighting foam concentrates that are fully biodegradable can be treated and disposed of by a range of general waste disposal facilities subject to their relevant waste acceptance criteria.

Firefighting foam concentrates that contain persistent contaminants such as fluorinated organic compounds must be disposed of by methods that ensure their complete destruction or immobilisation [55,75,54]. Disposal by high temperature incineration using plasma-arc destruction or injection into cement kiln processes is favoured for liquid wastes. Destruction in a cement kiln may also be feasible for contaminated soils or alternatively landfilling after fixation to immobilise all persistent organic pollutants.

3.3 Infrastructure contamination

Infrastructure such as pipework, rubber seals, flexible hoses, pumps, tanks, the floors of hangars and the surfaces of sealed fire-training pads that have been exposed to foam containing fluorinated organic compounds have been recognised as potentially significant and ongoing sources of contamination (e.g. of new infrastructure and stormwater) by fluorinated organic compounds from residues leaching out of such items.

For example, concrete and bitumen areas used for foam training have been found to retain fluorinated organics which are difficult to remove from their matrixes and may subsequently leach out of the surfaces and contaminate stormwater.

When carrying out maintenance, cleaning, decommissioning or replacement of such items the potential for short-term and long-term releases of residual contamination should be considered, risk assessments carried out regarding the potential for impact from low-level releases and mitigation measures adopted as appropriate.

4 Foam use issues

Firefighting foam is used across a diversity of industries that range from large-scale facilities to small mobile and hand-held applications. Each user group has to take into account the limitations imposed by their particular operational, health, safety, environmental and economic circumstances in choosing the type of foam and delivery systems that best meets their needs and obligations.

The following explanatory notes apply to the issues faced by some of these particular user groups in addition to the general considerations regarding the use of firefighting foam.

4.1 Fire brigades

Fire brigades are called on to deal with a range of large and small incidents involving various flammable solids and liquids. Accordingly they have on hand the types of firefighting foam that best suit the range of usual circumstances that require their use in industrial, urban and rural circumstances. Day-to-day fire brigade use of foam on spills and fires is sporadic and at unpredictable locations, most involving small-scale incidents such as at vehicle spills, industrial incidents and vegetation fires.

As a matter of course, each incident is assessed by the Incident Controller in terms of the scale of the incident and the potential for contaminants of any type to cause health impacts or environmental harm, whether from the foam in use or from spilled chemicals, fuels or fire residues, and to take any containment or clean-up measures that are necessary and practical.

When brigade appliances attend incidents at facilities where foam stocks and application systems are already present they have very little control over what type is available and how it will be applied and as a matter of course will use the foam stocks and systems present. If the Incident Controller has the opportunity, and it is safe to do so, it would be preferable to use fluorine-free foam stocks before using fluorinated foam where there is the potential for a release to the environment.

Where Fire Brigades are required to respond to a spill or fire at a facility that has existing firefighting foam and systems available on site it is the facility owner's or operator's responsibility to have:

- undertaken a proper risk assessment of the likely scale and impacts of an incident
- selected the most suitable foam for the risks and situation

- put in place containment measures as necessary
- made allowance for the potential involvement of fire brigade resources.

While Fire Brigades will endeavour to respond to an incident in the most effective way practical, the facility owner/operator is fully responsible for assessing the relevant risks on and off the site and for having in place the appropriate resources, measures, plans and procedures to control, contain and manage any releases to the environment of any contaminant. This includes having appropriate detailed response plans in place and having made appropriate choices about measures such as foam products, delivery systems and containment to achieve a best-practice standard for protection of life, health, environment and property.

Some industry operators are under the impression that once the Fire Brigade takes control of an incident that they are no longer responsible for the outcomes. That is not the case; the operator must have taken every reasonable and practicable measure to properly manage any foreseeable incident taking into account what scale and types of resources may be required to effectively deal with the worst-case incident.

Where fluorine-free firefighting foam is released to land, such as when used by an urban or rural fire brigade for ignition prevention, control, extinguishment, damping-down and training on vegetation fires, it is expected that no adverse effects will occur from the application of small amounts away from watercourses (e.g. less than ~500 litres of fully biodegradable, fluorine-free concentrate) across a wide area or fire front where all the foam will rapidly soak in and degrade in-situ. Significant releases directly to watercourses or other bodies of water should be avoided were possible.

Concentrated and repeated applications of fluorine-free foam, such as in areas where testing or training is carried out repeatedly onto a bare-earth area can result in the build-up of contaminants to the point where natural degradation is impeded by factors such as elevated concentrations of toxic components, depletion of oxygen and waterlogging. This raises the possibility of contaminants persisting long enough to be washed into adjacent watercourses or other water bodies by stormwater or to leach down to groundwater. In these situations there should be firewater control measures in place to prevent immediate releases to adjacent waterways or to any place that leads to such bodies of water and to assess whether groundwater is at risk.

Where firewater is generated, beyond that which can readily soak into the local soil to degrade, control measures such as bunding or ponds should be used to hold the water for at least 28 days to allow it to degrade before release and/or to evaporate.

Fire brigades should not have on hand or intend to use any firefighting foam containing fluorinated organic compounds that is intended for application on an area where it cannot be fully contained and the wastes appropriately collected and disposed of later. For example, roadside fuel spills or rural fire brigade use on bushfires.

4.2 Hydrocarbon refineries and large storage facilities

Fire protection measures at large hydrocarbon refineries and storage facilities are recognised as being of paramount importance to protect life, health, the environment and property. Many facilities are long-established with legacy-related restrictions such as their location adjacent to environmentally sensitive bodies of water, established roads and drainage layout, connections to third-party port facilities, limited space available for modification of operations and the difficulties in making changes to essential systems while continuing normal operations. This naturally places limits on their ability to make changes to procedures, systems and operations to keep pace with changing health, safety and environmental requirements.

Nevertheless changes need to be made over time to meet changing standards and obligations. It is recognised that for large industries significant planning and preparation needs to go into changes to essential systems associated with firefighting such as containment and control measures, delivery systems and foam type.

The emerging information regarding the previously unrecognised significant impacts of various aspects of firefighting foams on health and environmental values, as well as the occurrence of large-scale incidents such as the Buncefield (2005) and Coode Island (1991) fires, plus recent small-scale spills has culminated in the recent (but overdue) realisation that the risks of impacts from firefighting foam releases at all scales are no longer acceptable.

Hydrocarbon refineries and large storage facilities by their very nature require substantial fire protection systems with the attendant risk of the release of very large quantities of foam in contaminated firewater during incidents. This has the potential to have serious and long-lasting impacts on the adjacent areas, in particular in regards to damage to aquatic ecosystems that underpin a diversity of values such as ecological diversity, public amenity, recreational fishing, commercial fishing and aquaculture.

The legacy systems in place at existing large facilities almost certainly hold stock of foams such as fluoroprotein foams (FFFP) that are dependent on long-chain fluorotelomer (8:2Ft) PFOA precursor compounds for their effectiveness. These foams are not acceptable in the medium or long term as they effectively represent a potential release of PFOA to the environment (waterways, soils, groundwater, and atmosphere). In the meantime they must be fully contained in completely impervious bunding. Legacy systems may also contain or be contaminated with PFOS-containing foams.

4.3 Ports, shipping and offshore facilities

Fire protection measures for dock-side and on-water port facilities, oil and gas offshore exploration production facilities, and shipping face particular problems in being able to adequately protect life, health, the environment and property. As economic hubs for the transit of goods into and out of Australia it is essential to ensure that normal operation of facilities is not compromised and that any incidents are minimised in extent and duration.

Shipping, dock-side operations and oil and gas offshore exploration and production facilities present particular problems in regards to the release of any contaminants whether associated with wastes, chemicals, minerals, foodstuffs, hydrocarbons or firefighting foam. There are generally very limited opportunities to contain contaminants in large incidents that are not land-based, such as offshore facility fires and grounded ship casualties, plus the location of spills from shipping casualties is mostly unpredictable except that it can be assumed that an environmentally sensitive aquatic environment is almost always at risk with the potential for further dispersal of contaminants to other sensitive areas.

Regulations pertaining to systems and foam that off-shore facilities and international and domestic shipping are required to comply with and procedures to contain and deal with on-board firewater will have an effect as to what mitigation measures can be practically achieved and how much a facility, vessel or port operator may be able to influence how risks from incidents are managed. However, the Master of a vessel, the ship’s owner, the vessel’s insurer and the offshore facility operator are ultimately responsible for making good any damage that their vessel/facility cause in Australian waters and the port, shipping and/or offshore facility operator may have to deal with the ongoing effects of the incident.

Port, shipping and oil and gas exploration and production companies must demonstrate that their firefighting foam usage and firewater management meets ALARP environmental risk and best environmental practice.

A misconception that has arisen from time-to-time is the mistaken belief that foam used on a body of water can be contained and recovered in the same way as an oil spill by oil-recovery booms floating on the water surface. This is not the case, firefighting foams are *water soluble* and while there may be some foam bubbles floating on the water surface the vast majority of the foam becomes dissolved in the water column.

The key issue for port, shipping and offshore facility operators to consider in assessing what are suitable firefighting measures and foam types for their purposes is that foam is inevitably released directly to the aquatic environment, that is, directly to the ocean, river or estuary from the dock-side fixed and portable systems, from the deck of the vessel, offshore platform and/or from response vessels such as firefighting tugs.

Where such a direct release to the aquatic environment is unavoidable the use of firefighting foams containing fluorinated organic compounds of any sort is not acceptable due to its persistence in the environment.

Only fully degradable foam that does not contain any persistent toxic compounds is acceptable for applications where there is a direct release to the aquatic environment. Short-term acute impacts, even if locally severe, are far preferable to the risk of long-term impacts that cannot be remediated with persistent toxic contaminants that contribute to the cumulative pollution load in the area or by dispersal further afield.

For all foams, including fluorine-free foams, there is a risk of short-term environmental impact from the acute toxicity of foam components such as the detergents and solvents as well as dissolved oxygen depletion impacts from BOD. In the case of shipping, port and offshore facility incidents the depth of water at the incident site is such that acute impacts from acute toxicity and BOD effects of non-persistent foam such as fluorine-free foam are unlikely to be significant given that dilution in the water column and dispersal by tidal flow will mitigate the risk of any immediate effects.

Any essential testing of systems for maintenance, safety proofing and certification purposes using foams that do not contain persistent toxic compounds is acceptable where the foam is fully biodegradable and releases are managed such that the risk of environmental harm is minimised.

4.4 Mobile plant and hand-held extinguishers

Mobile plant and hand-held extinguishers are relatively small-volume systems, generally only involving tens to hundreds of litres of dilute foam solution. Releases and wastes of this scale can usually be readily captured, cleaned up and disposed of.

Mobile plant, such as large mining vehicles, are required to have on-board systems for fire protection. These systems have specific specifications, certifications and other requirements including testing and maintenance at regular intervals. Given the mobility of the system and the relatively small volumes it is entirely practical for controlled releases to be properly contained and the wastes collected and disposed of appropriately.

The practice of releasing fluorinated foam wastes to the ground during discharge tests of mobile plant systems is not acceptable and a breach of environmental regulations. That is, it is a direct, wilful and entirely avoidable release to the environment of a variety of long-chain fluorinated compounds [13,12] that are known to be indefinitely-persistent and highly dispersible pollutants with the potential for health and environmental impacts though releases to bodies of water, groundwater, air or via contaminated soils and dust. They also represent a human health risk.

Foam wastes containing fluorinated organic compounds need to be collected, stored, transported and disposed of as regulated wastes with destruction by high temperature incineration or other acceptable means meeting regulatory requirements.

Similarly, biodegradable fluorine-free foams must not be released in a way that they are likely to cause environmental harm, such as by BOD impacts and acute toxicity effects if allowed to enter a body of water or groundwater. However, fully biodegradable foams with no persistent toxic contaminants may be able to be appropriately treated and disposed of on-site or at local waste treatment and disposal facilities. Unavoidable minor releases to ground are acceptable with no clean-up necessary provided that there is no significant potential for contaminants to affect bodies of water or groundwater.

5 Assessment standards and information

Significant challenges are faced by firefighting foam users, responders and regulators when managing the various aspects of firefighting foam use. This is hampered by the general lack of current chemical, health and environmental information as well as the lack of defined standards for distribution of key elements. The Management of Firefighting Foam Policy sets out baseline requirements for basic testing and information disclosure on which assessments and decisions can be reasonably based.

5.1 Safety Data Sheets (SDS/MSDS)

Foam users, regulatory agencies and incident responders are heavily reliant on there being appropriate, relevant, comprehensive and accurate information available on which to base management and response decisions and planning.

The safety data sheet (SDS) is the most relevant and readily available document for these purposes with various chemical behaviours and characteristics routinely cited plus a dedicated section (Section 12) for information on environmental and ecological hazards.

Existing systems and requirements for SDS to be provided with products, understood by the user and held on site in a defined location are well established. This gives users and emergency responders the best chance for access when required in an emergency. All key information regarding ecological effects should be integrated in Section 12 of the SDS. Separate product brochures and supplementary information documents are rarely ever kept with the product SDS.

Given that firefighting foam can be applied at various different concentrations, intentionally or otherwise, the information in the SDS for firefighting foam must, where possible, be clearly expressed as being for the concentrate or product as sold. This may be supplemented by additional information on standard dilutions if that is considered operationally helpful.

To date significant problems have arisen for foam users, environmental regulators and incident responders in that information available in foam product documentation and in particular SDS have been very rarely adequate for environmental assessment purposes [**3**,**17**,**32**] with issues ranging across:

- SDS are out of date and no longer valid (>3 years old from publication date), for copies held on site as well as from some manufacturers/suppliers web sites.
- Very limited or a complete absence of relevant environmental information.
- Omission or non-disclosure of information on presence and effects of persistent compounds.
- Claims of biodegradability contradicted by the presence of highly persistent toxic compounds.
- Acute toxicity tests only reporting third-party test results for selected components and no tests carried out on the final foam formulation (i.e., no assessment of the overall synergistic effects of the components when combined in the formulation).
- Omission of information on toxic compounds such as preservatives and biocides.
- Failure to pass-on and disclose toxicity, persistence and hazard warnings provided by formulation component manufacturers.
- Non-relevance of the species used in toxicity tests.
- Non-standardised toxicity test periods (e.g. across SDS for 24, 48, 96 hours).
- Quoting of compliance with limited dangerous goods or other standards, worded so as to imply blanket compliance or approvals in other areas.
- Disingenuous statements that refer the user/responder to the "*local EPA*" as the authority for environmental impact information for a particular product where the "*local EPA*" will clearly not have any relevant information available for what are complex and usually "*trade secret*" formulations.

Some users, and even some regulators, have assumed that safety data sheets must meet an adequate standard in terms of information content, relevance and accuracy. Many are not aware that the SDS standard set by *EC Commission Directive 91/155/EC of 5th March 1991* is very broad in order to cover a vast range of substances and essentially only sets out the Sections that need to be included in SDS. Traditionally SDS have been documents focussed on workplace health and safety issues, and then mostly focussed on short-term acute health impacts, with only relatively recent regard for the inclusion of even very basic environmental information [36].

The Australian National Industrial Chemicals Notification and Assessment Scheme (NICNAS) has similarly been focussed on SDS and label information content on health and safety issues associated with use and handling and on higher order obligations such as those under the *Stockholm Convention* [91].

The Foam Management Policy sets out the required minimum standards for test and composition information that must be made available so that users, regulators and incident responders can make reasonable assessment of the environmental risks. The level of information required is not such that proprietary formulations are at risk of disclosure, although there must be general and consistent disclosure of the presence of toxic and persistent components and impurities.

The minimum standards set also provide a common base for users to make appropriate comparisons, decisions and fair choices about what suits their application best when all performance, health, environment, regulatory and cost issues are considered. Manufacturers and suppliers may choose to enhance SDS content by providing additional relevant information and users may need to seek further information to address particular or unusual circumstances they face.

The inclusion of standardised, comprehensive, verified information in product information and SDS will also be of an advantage to manufacturers and suppliers as appropriate disclosure will give the user confidence as to whether or not the product is credible and fit for purpose against all their requirements and obligations.

5.1.1 SDS preparation

Manufacturers or importers of chemicals into Australia are responsible for providing an SDS that has been prepared in accordance with the Australian Workplace Health and Safety Regulations, and should check that any SDS prepared against overseas standards meets this.

The Safe Work Australia *Preparation of Safety Data Sheets for Hazardous Chemicals–Code of Practice (2011)* [36] provides guidance on the content that should be included in an SDS. A particular note is made in this Code that *"While this Code applies to hazardous chemicals as defined, an SDS should be provided for any chemical that may adversely impact the health or safety of persons or the environment"* and that the *"SDS should reflect what is currently known about the chemical"*.

Guidance on content for SDS is constrained by the fact that SDS have to cover a very wide diversity of chemicals and substances across many industries and many jurisdictions, so there has been heavy reliance on the manufacturer to determine what is relevant content. Inevitably there have been inconsistencies and highly variable quality-of-information across manufacturers, even for products put to very similar uses and of similar composition.

5.1.2 Ecological information *(SDS Section 12)*

Section 12 – Ecological Information of SDS is the most relevant section that *should* contain comprehensive and relevant information about environmental effects. However, the information from many other SDS sections on the product characteristics and behaviour will also be highly relevant and should also be considered when assessing the potential for adverse impacts on environmental values.

These *Explanatory Notes* and the *Management of Firefighting Foam Policy* provide clarification of what the basic content of at least Section 12 (and possibly other sections) of the SDS should cover and the issues that should be considered in risk assessment and decision making for management of foam.

There is very little coordinated, independent quality control on the accuracy and relevance of SDS content, especially in regards to environmental effects for firefighting foam with SDS suffering from a significant lack of disclosure of key information that would be readily available or could be easily determined [17,15,16]. Given that the end-user ultimately assumes the liability for any product's use and its effects, it is also the user's responsibility to seek any further information regarding the product's fitness for purpose or any adverse effects it may have on health or the environment.

For users to be reasonably expected to assess their potential risks/benefits and liabilities for health, user safety and the environment, make informed choices about products and put into place associated controls, plans and measures to address health, safety and environmental issues, there needs to be more comprehensive and standardised information made readily available in product information and safety data sheets produced by suppliers.

The manufacturer or producer has responsibility for each of their products; after all they are the only ones who have knowledge of exactly what went into each of their products. *The testing required by the Policy is not onerous and only needs to be carried out once for each formulation. This is no different to other certifications such as testing for firefighting performance for each formulation.*

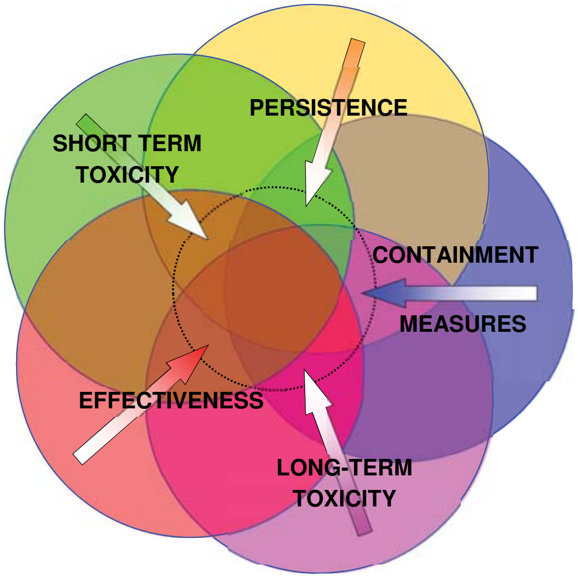
The end-user is not expected to undertake or duplicate the testing required by the Policy, as has been erroneously suggested to some users. However, the end user is ultimately responsible for seeking complete and appropriate information in regards to the suitability, performance and any health and environmental effects of the product(s) they consider or use.

A good guide to general SDS content and interpretation with coverage and explanation of all the essential elements of the sections including *Section 12 – Ecological Information* has been adopted by ExxonMobil for their products in their 2011 *User's Guide to Safety Data Sheets* [92]. This guide takes into account changes resulting from both *REACH Regulation (EC) № 1907/2006* as well as the *Classification, Labelling & Packaging (CLP) Regulation (EC) No 1272/2008* that implements the Globally Harmonized System in Europe.

Complementary to the *ExxonMobil Guide* is the 2012 *REACH and Safety Data Sheets* information leaflet [93] published by the UK Environment Agency as the REACH Competent National Authority which outlines the content and provision requirements for SDS.

To address their responsibilities and liability, and to ensure that there is no misunderstanding about products put into service, end-users would be prudent to ensure that they seek and receive written confirmation of any information provided to them that is additional to that in the published SDS and product information.

6 Balancing considerations



Balancing the considerations

Firefighting foams are a valuable and essential tool for protection of life, environment and property and incidents ranging from minor spills and fires to major incidents will continue to necessitate their use on land and at sea

As has been pointed out in submissions, and in large part is the main purpose of the Policy, the risks associated with firefighting foam use must be considered proactively, well before foam is put into service. This is especially important considering that during an incident the Incident Controller will have very few options open to them and very little time in which to consider them.

The Management of Firefighting Foam Policy recognises that a prime consideration when choosing and procuring firefighting foam is the effectiveness of the foam for the intended firefighting application in providing adequate levels of performance, safety and property protection.

The system and foam options available that meet the appropriate performance standards and the user's operational needs must also be assessed in terms of a net environmental benefit analysis [94] to select the optimal combination amongst the available options that best addresses *all* requirements or fitness for purpose [3], including the relevant environmental protection standards.

All firefighting foams have the potential to cause adverse health and environmental impacts and must be managed proactively. The potential for releases, and therefore impacts, has been shown to be not only from their infrequent large-scale use on incidents but also through less obvious areas where there are less noticeable but more frequent releases.

The risks of impacts from releases range across:

- Large-scale, high-profile, very infrequent incidents where large amounts of contaminants of various type are usually released.
- Accidental spills, servicing, testing and training activities where moderate amounts of contaminants are released.
- Small scale spills from accidental spills and poorly managed maintenance and testing activities.
- Improper waste disposal through systems incapable of capturing and destroying contaminants, e.g. processing fluorinated foam wastes from fires or testing through wastewater treatment systems incapable of capturing fluorinated organic contaminants [89,61,62].

6.1 Large-scale release risks

Large-scale incidents such as the 2005 Buncefield hydrocarbon storage fire in the UK [77,95] are fortunately infrequent, however there are a range of smaller-scale incident that go unrecognised and unreported that contribute to the cumulative effects of some foams. During the Buncefield incident 750 tonnes of fluorinated foam concentrate was used (including significant quantities of PFOS) with about 12 megalitres (of a total of 16 megalitres) firewater still remaining to be disposed of. About the same amount was released to the environment which also resulted in part of north London's groundwater drinking water supplies being compromised.

A large release of firefighting foam from a large fuel terminal, port facility or shipping incident, for example, in or adjacent to Queensland coastal waters (similar to the Coode Island incident at the Port of Melbourne in 1991 [96], involving about 200 tonnes of foam concentrate [78]), would, depending on location, have the potential to impact on a significant part of Queensland's $436 million per annum fisheries and aquaculture sectors [81] through contamination (or perceived contamination) of seafood and loss of local and overseas markets/reputation for quality.

By comparison, a large-scale incident involving foams formulated with non-persistent, fully-biodegradable compounds would be in-the-main self-remediating over a relatively short time with only short-term acute toxicity effects. In such cases the main focus would be on the impacts of the other contaminants and combustion products from the incident.

6.2 Small-scale releases

The potential for large-scale, but very infrequent, incidents tends to dominate discussions and considerations of risks while the less obvious chronic release categories are largely ignored. This is despite small-scale spills and fires, servicing, testing, training, maintenance and spills being common [65,45,17,79] and contributing very significantly to the risk of adverse impacts in the long term from poorly managed and generally unnecessary releases.

Recent examples of significant cumulative impacts include a rising number of cases of spills and legacy contamination from airport firefighting training areas contaminating surface and groundwater values. The Army Aviation Centre at Oakey is a current example where it has been found that a plume of groundwater contaminated by PFOS over a long period extends several kilometres down-gradient from the source fire training ground with impacts on significant numbers of domestic and agricultural users accessing water from bore holes in that area [97].

The risk of impacts from the smaller, more frequent releases is exacerbated by lack of information available to the end-user against which they can assess the risks for their particular situation and make informed decisions about appropriate management measures they should have in place.

6.3 Considering the choices

Users need to carefully consider what combination of foam type, application systems and containment measures are best for their application and location. Achieving that balance requires consideration of a range of competing and sometimes opposing factors. What was previously an acceptable balance may change over time so needs to be factored in to choices and planning for continuous improvement to systems in the longer term.

For example, PFOS has been an exemplary compound for firefighting for some types of fires but its serious adverse impacts on health and the environment mean that it has not been acceptable in formulations for some time. Despite the widely available knowledge of the high risks attaching to PFOS some industry users have failed to move to address the issue without regulatory intervention. Similarly PFOA and PFOA precursor compounds are being found to carry unacceptable health and environmental risks and most jurisdictions recognise that moves to phase out their use must occur as soon as practicable.

The lessons from the use of these and similar compounds have reinforced the need to apply the *precautionary principle* in the management of potential releases of contaminants, not only when adverse effects have become plain, but also when there are indications of such effects and there is insufficient information available to make a reasonable and informed assessment. It is irresponsible to release chemicals into the environment that will cause irreversible, planetary contamination unless it has been established that such chemicals are benign to the environment and human health [29].

Put simply, the *Absence-of-Evidence* for an adverse effect is not *Evidence-of-Absence*. In the case of fluorinated organic substances there is now more than adequate evidence and indications that our use of products containing any such compounds should be very cautious as the releases are unrecoverable, undegradable and the adverse effects may be substantial, permanent and ongoing. From a regulatory standpoint the *precautionary principle* must apply with the onus on the user/proponent to demonstrate conclusively that no adverse effects can occur.

Accordingly if new generation shorter-chain C6-based fluorinated foam products are to be used there needs to be careful control in terms of their purity and management as the information on their properties and effects is very limited [98,71,29] with significant indications that the *per*- and *poly*-fluorinated compounds with various functional groups (as well as fluoropolymers) share properties and effects with the fluorinated organic compounds already of serious concern.

Where feedstock chemicals used in the production of foam formulations state that the feedstock materials have characteristics such as "*Toxic to aquatic life with long lasting effects*", "*Toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment*", or that some information is not available for key attributes such as PBT/vPvB assessment, this information must be disclosed as a matter of course in the final product SDS so that end-users, responders and regulators can make informed assessments and decisions.

For the end-user of firefighting foams to make informed and soundly based risk assessments and decisions they need quality information and advice to include in their considerations as to what constitutes the best-practice combination of product, systems, procedures, containment measures and response planning that can best meet their various operational needs, regulatory obligations, health and safety standards, community expectations and economic goals.

7 Use of persistent organic compounds

Fluorinated organic compounds are the largest group of persistent organic compounds known to be very widely used in firefighting foam formulations, as well as in a wide range of other consumer products and industrial processes. Other compounds, such as siloxanes, may also be environmentally persistent depending on the specific compounds in use, therefore care must be taken to evaluate their effects and fate in the environment before they are put into widespread use.

The major concerns with fluorinated organic compounds after they are released to the environment include:

- diverse variety of compounds in use with little information on potential impacts of each
- permanent pollutants with indefinite environmental persistence
- known to have various toxic effects on health and the environment
- variously bioaccumulate in plants, animals and humans
- persist in the human body for a very long time (slow elimination)
- can be transported over long distances by the air, oceans, waterways and groundwater
- end-products will continue to circulate in the environment undegraded
- toxic effects may be cumulative and exerted over an extended period of time
- populations and environments far away from the point of release may be affected
- adverse impacts on environmental, heath, amenity and economic values may be irreversible.

Considerable world-wide health and environmental concerns have been expressed generally in a wide range of published papers and by regulatory agencies regarding the use of fluorinated organic compounds and the lack of information on production volumes, uses, properties and biological effects of existing and fluorinated alternative compounds.

7.1 World-wide concerns

In addition to the general concerns expressed regarding fluorinated organic compounds there have also been specific statements issued voicing the concerns of groups of eminent scientific experts who work on the characterization, properties, analysis, environmental distribution and adverse effects of poly- and perfluorinated alkyl substances (PFASs). This includes the recent *Helsingør Statement* [71] and *The Madrid Statement* [98] which specifically raise issues directed at informing and cautioning regulators, manufacturers, distributors and end-users including:

- The world-wide occurrence of PFASs in humans, wildlife and the environment.
- The lack of decline in the occurrence of some long-chain PFASs despite regulatory controls.
- The very limited knowledge on the properties and effects of PFAS fluorinated alternatives.
- The wide range of adverse health and environmental effects attributed to PFASs.
- Less efficient fluorinated alternatives may lead to increased use, emissions, and exposure.
- Concerns about low testing requirements for mixtures of substances.
- The need for world-wide regulation of production and use of PFASs of all types.
- The persistence of alternative PFASs and their transformation products.
- Increased exposure to alternative PFASs implies increased risk of unknown adverse effects.
- The lack of toxicological data on PFASs from manufacturers.
- The limited technical capacity to destroy PFAS wastes world-wide.
- The need for tighter regulation and controls on PFAS-based products.
- Greater transparency by manufacturers on PFAS product content and potential effects.
- Ceasing use of PFAS-based products where a safer alternative exists.
- The need to develop non-persistent, non-toxic alternatives to PFASs.

The publication of these statements are a very strong indication of the high level of concern amongst a wide diversity of professional scientists eminently qualified to comment on the use and release of persistent organic pollutants based on current facts and indications of the behaviour, fate and adverse impacts on human health and the environment of these compounds.

7.2 Ongoing use of fluorinated compounds

Firefighting foam formulations that use fluorinated organic compounds are very diverse in their (largely unknown) formulations. The *Management of Firefighting Foam Policy* does not preclude the use of all fluorinated firefighting foams, however, there are restrictions on the purity of fluorinated compounds that can be used and the measures that must be in place to contain and manage releases. This is in line with the general intent of the *U.S. EPA PFOA Stewardship Program* which set the initial baseline principles and goals underpinning the direction to be taken for management of compounds of particular concern. This now needs to be extended in the light of the better understanding of fluorinated organic compounds that has emerged since then.

Significant difficulties in being able to assess the potential impacts of fluorinated firefighting foams arise from the "*trade secret*" nature of fluorinated firefighting foam formulations (acknowledged as a valid issue) as well as the general lack of relevant testing results for foams in their as-sold, final form meaning that there is a lack of information for users, responders and regulators with which to assess possible impacts.

The Policy does not require that detailed confidential formulations of any foam of a "trade secret" nature be divulged but rather that meaningful information is provided on key issues for each formulation marketed for use including:

- Acute and chronic impact test results for the final product as-sold (toxicity and BOD).
- Biodegradability that takes into account all the compounds used in formulations.
- Indications of persistence and bioaccumulation potential of compounds used in formulations.
- Classes and purity of fluorinated organic compounds where they are used in formulations.

Significant evidence and indications of the potential for adverse effects on human health and the environment by the wide range of both long-chain and short-chain fluorinated organic compounds used in firefighting foam are common including:

- All fluorinated organic compounds used in foams are extremely persistent or partially degrade to extremely persistent compounds including both long-chain and short-chain compounds.
- All fluorinated organic compounds are toxic to varying degrees to human health and the environment.
- Adverse effects have been found or indicated in animals, children and adults including developmental toxicity, neonatal mortality, carcinogenicity, kidney and liver toxicity, immuno-toxicity and reproductive toxicity **[74]**.
- Longer-chain fluorinated organic compounds have been shown to be bio-accumulative.
- Shorter-chain fluorinated organic compounds have shown potential for bioaccumulation **[65]**.
- Shorter-chain fluorotelomer carboxylic acids are more acutely toxic than corresponding perfluorocarboxylic acids such as PFOA **[67,99]**.
- Fluorinated organic compounds have been found to persist in the human body with long elimination half-lives for long-chain compounds and even longer for shorter-chain compounds (Table 9.2 A – C8, 2.3 to 5.4 years, C6, PFHxS 8.5 years) increasing the potential for bioaccumulation in humans so that comparatively low exposures can result in large body burdens **[38,74]**.
- Shorter-chain fluoroteleomers such as 6:2FtS persist and continue to concentrate in groundwater a decade after use has ceased at some sites **[18]**.

As an example of fluorotelomer behaviour and persistence; The Tyndall Air Force Base (in the USA), which operated until 1992, used AFFF, (supplied ~1983-88), for firefighting training:

- Foam concentrate sample was found to have 12,000 ug/L 6:2FtTAS and 6,000 ug/L 8:2FtTAS (-thioamido sulfonates) with no 6:2FtS detectable in the concentrate.
- In 1999 groundwater samples from all four bore holes on site were found to have exceptionally high fluorotelomer sulfonate concentrations (6:2 & 8:2FtS >10,000 ug/L) **[18]**.

These are assumed to have been derived from the partial degradation of the fluorotelomer thioamido sulfonates (X:Y-FtTAS) in the original foam concentrate.
- The fluorinated organic compounds in the groundwater samples consisted of 82% X:Y fluorotelomer sulfonates, 16% perfluoro sulfonates (probably mainly PFOS) and 2% perfluorocarboxylates (presumably PFOA and PFHxA).

This demonstrates:

- Production in the environment of 6:2FtS and 8:2FtS from thioamido sulfonate compounds.
- Persistence of the fluorotelomer sulfonates in the groundwater over a period of about 11 to 16 years (implying the need to consider X:Y-FtS compound effects over this extended period and not just the end-point compounds).
- Probably some production of PFOA and PFOS from precursor compounds.

Similar persistence of fluorotelomers in groundwater and soils is coming to light for a range of other facilities [63,79,80,97,18,100].

The effects of the various compounds on human health must also be considered not only in terms of exposure to the initial compounds but also in terms of the intermediate and end-point metabolic degradation products as the compounds interact within the various compartments and organs in biological systems [85].

This highlights the need to consider the potential for impacts to health and the environment in the short, medium and long term for fluorotelomers, intermediate partial degradation products and their end-point compounds. There is currently very little information available on the behaviour and effects of such compounds.

7.3 U.S. EPA PFOA Stewardship Program relevance

The U.S. EPA Stewardship Program which was put into place in 2006 [9,56,47] obtained commitments from eight global chemical companies to:

- By 2010 – reduce product content of PFOA, higher homologues and precursors by 95%.
- By end of 2015 – eliminate PFOA, higher homologues and precursors.

The *Stewardship Program* relates to production and new products and does not take into account that there are existing long shelf-life legacy stocks of products containing PFOS, PFOA, PFOA precursors, etc. still widely held that could be released. It also is not relevant to, and does not provide assurances about, products sourced from other countries and made by other companies that are not party to, or supportive of the Program.

The *U.S. EPA PFOA Stewardship Program* has provided some good initial direction relevant to fluorinated firefighting foam development and control in the U.S., and by inference other countries, but it is not comprehensive and consideration of the broader issues and information that has become available since its establishment in 2006 is required.

The OECD is expected to take over the *US EPA PFOA Stewardship Program* function and is considering how best to develop, facilitate and promote national and international product stewardship programmes and regulatory approaches for perfluorinated chemicals based on their existing work programmes and in association with other participating organizations of the IOMC [20].

The Management of Firefighting Foam Policy has taken into account a significant amount of more recent information that has emerged since the agreement in 2006 and bridges the gap between production-focused controls, production by companies who did not subscribe to the U.S. EPA PFOA Stewardship Program and the immediate risks associated with the continued use of legacy products by users not recognising the risks and voluntarily embracing the need for change.

For example, large stocks of PFOS foam are known to be still deployed potentially for immediate use in various systems on and adjacent waterways around Australia (and elsewhere) despite the current understanding of PFOS's adverse effects and its listing as a Persistent Organic Pollutant under *Annex B* of the *Stockholm Convention* since 2009 [60]. An incident involving a one tonne spill of PFOS foam occurred in Queensland to a body of water connected to the *Great Barrier Reef Marine Park* in January 2013.

7.4 Long-chain fluorinated organic compounds

The OECD definition of long-chain fluorinated organic compounds refers to perfluoroalkyl carboxylic acids with seven or more perfluoroalkyl carbons (i.e., ≥7 perfluorinated carbons) and perfluoro-alkane sulfonates with six or more perfluoroalkyl carbons (i.e., ≥6 perfluorinated carbons) [60]. The ‘‘long-chain’’ definitions for carboxylates and sulfonates are different in number of C atoms because a sulfonate with a given number of carbons has a greater tendency to bioconcentrate and/or bioaccumulate than a carboxylic acid with the same number of C atoms and therefore behaves like a long-chain fluorinated organic compound.

Although the OECD 2011 definition does not include perfluoroalkyl substances other than carboxylates and sulfonates, other compounds, with functional groups such as betaines, amines, thioethers, etc., with a perfluoroalkyl chain ≥8 are similarly considered long-chain [9,56,60].

The carbon chain length is not the only factor influencing toxicity, mobility, bioaccumulation, etc. The type of compound (e.g. fluorotelomer alcohol, sulfonate, carboxylate, betaine, etc.) and whether all carbon atoms are fluorinated have a bearing and must be considered. For example, fluorotelomer carboxylic acids (FTCA) are generally more toxic by one to four orders of magnitude to aquatic organisms than the corresponding perfluorocarboxylic acids (PFCA) [34,99].

Many firefighting foams currently deployed still rely heavily for their effectiveness on long-chain fluorinated organic compounds (e.g. 8:2Ft, 10:2Ft) which are of significant concern for human health and the environment in themselves and because of their degradation products. This means that foams that contain PFOS, PFOA, their precursors and higher homologues need to be taken out of service as soon as practicable.

PFOS has been of particular concern for some time as a persistent organic pollutant under the *Stockholm Convention* and has well known adverse health and environmental effects. As a matter of priority PFOS foams must be taken out of service *as soon as possible* and must not be used. Many instances of PFOS foam still being in service in Australia are coming to light.

The *European Union Commission Regulation (No. 757/2010)* required that all foam containing PFOS above 10 mg/kg (0.001% w/w or 10 ppm) must not be used after 27 June 2011 and this was adopted by the UK Environment Agency in February 2011 [53,58]. Accordingly:

- The maximum allowable impurity for PFOS in any firefighting foams has been set in the Policy to 10 mg/kg.
- Foams that contain PFOS above 10 mg/kg impurity limits are of greatest concern and must be taken out of service as soon as possible and must not be used.

Canada prohibited the use of foam containing PFOS above 0.5 ppm (0.00005%) from 29 May 2013 [63,101] in Regulations that came into force on 29 May 2008. New Zealand also excluded PFOS and PFOA from use in any solid or liquid substances that are imported or manufactured for use as a fire fighting chemical in the *Fire Fighting Chemicals Group Standard 2006* under the NZ *Hazardous Substances and New Organisms Act 1996.*

Foams that contain PFOA, PFOA precursors and their higher homologues (including fluoropolymers) at overall concentrations above 50 mg/kg are of similar concern and must be taken out of service as soon as practicable and must not be used. Relevant to the practical implementation of this is:

- Stocks of PFOA-contaminated/PFOA-precursor containing foams are still in service and time is required to properly consider replacements.
- Changes to foam delivery systems may be necessary and timeframes for replacement are to be negotiated on a case-by-case basis.

- Agreed individual plans will be put into place detailing how and when changeover is to be achieved.
- All PFOA-contaminated/PFOA-precursor containing foams are to be out of service by no later than two years from the Policy being approved. This provides for a changeover period beyond the anticipated timeline for the elimination of PFOA and related compounds from products by the end of 2015.

7.5 Short-chain fluorinated organic compounds

Foams based on formulations using high-purity, short-chain (≤C6) fluorotelomers have been under development as alternatives to the more toxic, more bioaccumulative, longer-chain compounds. This is in line with the *U.S EPA PFOA Stewardship Program* goal of elimination of PFOA, PFOA precursors and higher homologues by the end of 2015.

While there has been progress in moving towards shorter-chain C6-based foams there are still many foams, some promoted as "*predominantly C6*", which still rely heavily on a significant proportion of long-chain compounds in their formulations (e.g. up to 75% C7-9, up to 32% C8-12) [**13**,**12**,**20**].

There are a wide diversity of compounds with six perfluorinated carbons that are used in foam formulations (Tables 2.1 A & B) with no doubt more to be reported, each with different characteristics and (largely unknown) effects. Six-carbon perfluorinated compounds (and shorter) are reported to be generally less toxic and less bioaccumulative than the longer-chain compounds and therefore have been considered as potential replacement compounds.

The development of C6-based foam formulations, initiated by the *US EPA PFOA Stewardship Program*, has been underway for some time (2006) and has provided the opportunity to transition away from foams based on long-chain C8 compounds (and their homologues) and to develop and assess C6 foams of potentially lower risk.

However there is still insufficient information publicly available to conduct realistic risk assessments with major gaps in information [**16**,**74**] with:

- Few indications of the proposed fluorinated alternatives with many probably still unidentified.
- For identified alternatives, information on their behaviour, fate and potential impacts on health and the environment is insufficient.
- Proposed volumes of fluorinated alternatives that might be used and released are unknown.

The use of new generation fluorinated foams that have in their formulations (or will have) shorter-chain fluorotelomers (e.g. 6:2 Ft) needs to be qualified as there still needs to be appropriate management as there are a range of concerns, some that have arisen or have been better elucidated since the 2006 *US EPA PFOA Stewardship Program* commenced.

Significant issues that need to be considered for short-chain fluorinated organic compounds include:

- End-point perfluorinated compounds produced by degradation have the same extreme persistence of all other perfluorinated organic compounds.
- The functional groups on the compounds strongly influence their properties (e.g. the differences between betaines, carboxylic acids and sulfonic acids in acidity (pKa), acute toxicity, bioaccumulation and bioelimination).
- The partial degradation/transformation steps, intermediate products, half-lives and environmental effects of fluorotelomers are poorly known [**47**]. For example, 6:2 fluorotelomer mercaptoalkylamido sulfonate (FTSAS), common in many AFFF, is regarded as a potential source of fluorotelomer sulfonates, fluorotelomer alcohols and fluorotelomer carboxylic acids [**15**]. Processes similar to the biotransformation of 6:2 FTOH may occur which involves nine intermediate products through 6:2 FTCA, PFHxA to PFBA [**47**].

- Many still show the same PBT characteristics of longer-chain compounds albeit at reduced levels [65,18] e.g. PFHxS (C6) is regarded as having the characteristics of a "long-chain" sulfonic acid [60] and PFHxA has higher ecotoxicity than PFOA to aquatic species [29].
- Short-term acute effects are largely unknown or unpublished.
- Long-term chronic effects are largely unknown [42,47,99].
- While in *X:Y* fluorotelomer form the compounds have at least an extra two carbons in the chain e.g. a 6:2Ft is eight carbons long until it partially degrades.
- Short-chain compounds are *not* non-toxic and not necessarily non-accumulative [65]. For example 6:2FtS is persistent in groundwater [18] and exhibits similar levels of liver and reproductive toxicity to PFOS [37].
- Mobility in soils and water (and therefore dispersal) is generally higher for the shorter-chain compounds [6,60,42,29] with likely higher uptake into leaves, stems and fruits [29].
- Combinations of different fluorotelomers are used in foam formulations with little information available on their single or combined synergistic effects and those of their breakdown products [18].
- The breakdown product of many current C6 fluorotelomer-based foams is 6:2FtS [20] which is regarded as a "long-chain" and has a greater tendency to bioconcentrate and/or bioaccumulate than a PFCA with the same number of C atoms e.g. C6 PFHxA [9].

Potential degradation products from the new fluorotelomer products and raw materials include the 5:3 acid, PFPeA (perfluoropentanoate) and PFHxA (perfluorohexanoate), depending on environmental conditions [102]. A study of ski-wax technicians exposed to PFCs showed that the perfluorocarboxylic acids PFHpA, PFOA, PFNA, PFDA and PFUnDA all bioaccumulated, with PFHxA having a relatively short half-life in man compared to other perfluorocarboxylic acids [103].

Measurements made of groundwater concentrations at former US military firefighting foam training sites indicate that PFOS, PFOA and 6:2 FTS all have environmental half-lives of at least a decade, with some samples still foaming 10-15 years after the sites were last used [18]. Similarly in Norway 43 airports that had previously used fluorinated foams were investigated for PFC contamination [100] with PFOS, 6:2FtS and other PFCs found to be present in soils, surface water, groundwater and biota.

The *U.S. EPA PFOA Stewardship Program* and the agreements that were entered into by the major chemical companies do not provide any guidance on what the final quality targets are for the "*elimination of PFOA, PFOA precursors and higher homologue chemicals*" from products [104] in terms of allowable impurities although there has been some progress on understanding what is desirable and what is achievable. Clearly total 100% elimination with no traces of impurities whatever is not practical or measurable, so achievable targets need to be set and have been considered in the Policy.

As a benchmark for achieving the Stewardship Program goals DuPont has indicated in technical information (2008 & 2012) that its foam feedstock Capstone™ products (1183, 1157 & 1157D) [105,106] meet the goals of the *US EPA 2010/2015 PFOA Stewardship Program* with a PFOA impurity target below LOD (limit of detection) where LOD is referenced to a method appropriate for PFOA, precursors and higher homologues [107] with a LOD in the range *sub ug/g and LOQ ug/g* (ug/g = mg/kg or ppm w/w). DuPont also indicated in 2009 that PFOA content in aqueous-based dispersions will be or have been reduced *to a level below 50 ppm* [108].

This limit is supported by 2010 industry estimates based on an assumption of less than 1 ppm PFOA impurity in AFFF having up to 0.5% fluorotelomer content [20] compared to older generation foams with 0.9% to 1.5% w/w of fluorinated organic compounds [44].

The foam Policy therefore considers a limit of 50 mg/kg for PFOA, PFOA precursors and higher homologues, as impurities in the foam concentrate, to be a reasonable and achievable standard for impurities in short-chain fluorotelomer-based foam formulations. The limit on PFOS is dealt with separately.

7.6 Alternatives to fluorinated compounds

The growing recognition of the environmental and health problems associated with fluorinated organic compounds has driven investigation of alternative fluorine-free and other non-halogenated compounds that may impart similar beneficial firefighting characteristics to firefighting foams, particularly those that may have the ability to form aqueous films, such as trisiloxane surfactants.

As with any new product the development phase must include close scrutiny of the potential adverse effects on health and the environment so as to avoid the past mistakes of putting into service unsuitable and damaging products.

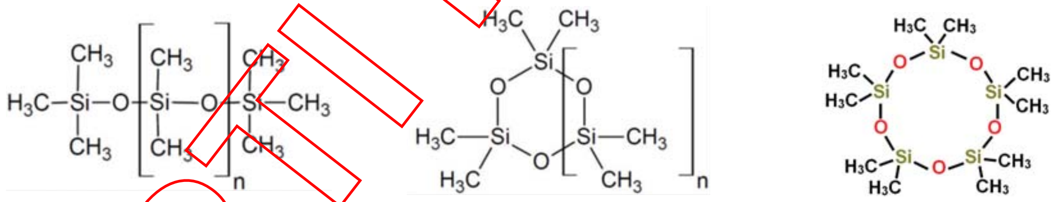
Siloxane surfactants have recently emerged as a promising alternative for formulation of halogen-free AFFF where the siloxane group in various carbohydrate siloxane compounds forms the hydrophobic part of the surfactant [109]. However, associated publications refer to "*environmentally-sound high-performance siloxane surfactants*" [110] and "*environmentally friendly*" [111] without any reference to, or elucidation of, the basis for stating that that the proposed surfactants are acceptable in terms of even the primary issues of persistence, biodegradability, BOD, COD, bioaccumulation or acute and chronic toxicity.

All foams have the potential to cause significant environmental harm, even if only through short-term detergent toxicity and BOD effects in water bodies, so none can be validly described as "*green*" or "*environmentally friendly*" as is sometimes used in promotional material.

The siloxane compounds most commonly in general use have been identified as variously being environmentally persistent, bioaccumulative, toxic, having the potential to cause health issues such as endocrine disruption, liver and lung injury and have the potential to cause ecological harm [112,113].

Siloxanes can be grouped into three structural groups (Figure 7.6 A) [112,109,114]:

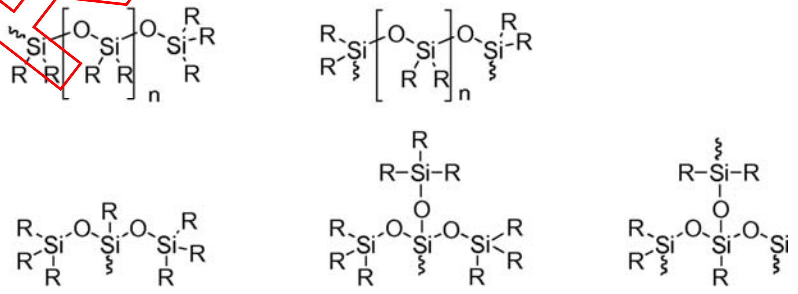
- Cyclic siloxanes, having a closed-ring structure such as methyl siloxanes expressed as D_n where (n) is the number of silicon atoms in the ring (e.g. D_4, D_5 & D_6).
- Linear siloxanes compounds, expressed as L_n, having (n) silicon atoms in a chain-like structure (e.g $L_4 – L_{17}$)
- Branched and linear siloxanes attached to a functional group (e.g. carbohydrate).



Linear (L_n) poly-dimethylsiloxane (After Hong *et al* [112])

Cyclic (D_n) methyl siloxane

D5 - Decamethylcyclopentasiloxane



Branched & linear siloxane groups of carbohydrate surfactants. R = ethyl or methyl group, n=0-10 (Blunk *et al* [109])

Figure 7.6 A – Siloxane structural groups

Based on chemical principles, non-cyclic siloxanes with biodegradable functional groups such as carbohydrates may be biodegradable with low or limited persistence. However, this is not evident from the published papers that were reviewed as most research has focussed on cyclic methyl siloxanes (e.g. D_n siloxanes) which exhibit various adverse effects [112,115,114,116,117].

8 Use of non-persistent foams

Given the intense focus on the problems and risks identified with foams that use fluorinated organic compounds such as PFOS and PFOA in their formulations much discussion has been polarised in terms of "*fluorinated" versus "fluorine-free"*.

While this polarisation may be valid in terms of the differences in the underlying firefighting mechanisms between the main foam types, the underlying issues from an environmental perspective, beyond the acute short-term toxicity and BOD effects applicable to all types of foam, are more correctly about the use and impacts of foams with:

- Persistent toxic compounds with potential to cause long-term adverse impacts.
- Non-persistent toxic compounds with short-term adverse environmental impacts.

It is quite conceivable that a fluorine-free, firefighting foam could have long-term adverse impacts from the inclusion of persistent compounds or persistent breakdown products which may be toxic.

For example, *cyclic* siloxanes (used extensively in personal-care products, e.g. D5 Decamethylcyclopentasiloxane in Figure 7.6 A), have been considered for use in firefighting foams but found to be ineffective and have environmental persistence, bioaccumulation and toxicity characteristics that make their release to the environment highly undesirable.

Accordingly the term *fluorine-free* foam is used interchangeably to also mean *non-persistent* foam.

All firefighting foams can have adverse environmental impacts. There is no foam that is completely environmentally benign. As is the case with fluorinated foams there are many diverse formulations of non-persistent, fluorine-free foams and all need to be assessed for firefighting effectiveness for the particular application as well as assessment for their potential environmental impacts against the relevant criteria. The primary environmental impact concerns for fluorine-free foams are their biochemical oxygen demand when released to bodies of water and groundwater and their short-term acute toxicity, primarily due to the synthetic detergents and solvents in their composition.

The general claim that has been circulating that "*fluorine-free foams do not work*" in terms of firefighting performance is disingenuous. The same high performance certification standards are applied to the testing for all foams regardless of their composition with rigorous tests carried out by independent certification organisations to the agreed standards. Foam must be selected according to the particular application. Many fluorine-free foams are acknowledged as "*meeting the toughest amongst the firefighting standards*" [20,118,23,109] and exceed film-forming fluorinated foam performance in various circumstances. Similarly the performance of AFFF is variable with some aqueous film forming foams (AFFF) failing to form aqueous films under some circumstances.

Even a brief review has found that various fluorine-free foams from a range of manufacturers meet the independent certifications for all the major firefighting applications including *LAST Fire Test, EN1568(1-4), DEF(Aust)5706, ICAO Level B&C, AS5062* and reputedly *US Mil Spec/UK Defence Spec* in terms of performance but not in terms of the legacy requirement in Mil Spec to have a specified fluorine content (which may be under review).

Performance certification authorities that undertake these tests include MPA Dresden, CAAi UK, FM Approvals, Underwriters Laboratories Inc., SP Technical, Resource Protection International, SP Sweden and DNV Norway.

A cursory investigation of the extent of fluorine-free foam use around the world (with a focus on Australian use given the Policy relevance to Australia) found about 183 fire brigades, facilities and corporations that are using fluorine-free foams including at least:

- Airports – 23 Australian (predominantly Air Services Australia), 54 overseas.
- Fire brigades – 5 Australian, 19 overseas.
- Corporations – 13 Australian, 34 overseas.
- Ports – 12 Australian, overseas ports not investigated.
- Petroleum products – 7 Australian, 13 overseas (including offshore oil and gas platforms).

At present hand-held foam-type fire extinguishers are the only extinguisher type where a fluorine-free foam has not yet been certified for use but development is reportedly underway for a fluorine-free foam to comply with AS1841. In the meantime it is eminently practical for the small amounts of fluorinated foam, contaminated materials and wastes produced in hand-held extinguisher incidents and servicing to be dealt with appropriately. This being implemented properly will largely depend on the supplier making the user aware (in Section 12 of the SDS and other documents) of their liability and the requirement for containment and clean-up of wastes containing persistent organic pollutants.

The general marketing claim that all fluorine-free foams are "*10 times more toxic"* (than fluorinated foam) is also without foundation, or at best is a claim that is out-of-date and refers only to acute short-term toxicity. A brief review of acute toxicity across foam types (where there is sufficient information to do so in SDS) finds similar relative toxicity and overlap in values such as LD50 and LC50 depending on manufacturer and foam type [26]. The potential health, safety and environmental effects of each foam need to be assessed in terms of not only their acute short-term toxicity (the most basic and often-quoted measure) but also the potential for long-term chronic toxicity effects, as well as environmental persistence, which have so far rarely been considered.

A further argument levelled against fluorine-free foams, again based on no consistent, verifiable evidence has been that so much more will need to be applied and more frequently in an incident. Even if it were to be necessary to use higher concentrations or larger amounts (on very infrequent events), the resulting short-term, but recoverable and naturally remediating damage is preferable to permanent pollution events that have no prospect for recovery or break down of persistent contaminants and represent a long-term threat to the environment.

In comparison to fluorine-free foam use, the proposed alternative pure C6 short-chain fluorinated compounds reportedly may require greater concentrations of the fluorinated organics in their formulas to achieve the same firefighting performance so it could be said that this may result in larger amounts of persistent organic contaminants being released than for legacy foams. This could therefore negate the lower (short-term) toxicity and bioaccumulation characteristics of the proposed alternative shorter-chain compounds and result in health and environmental exposures for compounds where little is known of their behaviour and effects [98,71].

9 Policy implementation

The *General Environmental Duty* (GED) under existing environmental legislation requires that any person, corporation or organisation carrying out an activity must take all reasonable and practicable measures to prevent or minimise the potential for the activity to cause environmental harm, having regard to *the current state of technical knowledge for the activity and other relevant matters*. Failure to comply with the GED obligations under the legislation could result in statutory action by the regulatory authority. Similarly knowingly causing environmental harm through the release of a pollutant is an offence that can result in statutory action by the regulatory authority.

Sites that carry out their activities under licences required by environmental legislation may also have additional specific obligations to comply with licence conditions regarding how they carry out the licensed activity and what they are permitted or not permitted to release to the environment.

All firefighting foams have the potential to cause environmental harm, particularly in bodies of water through impacts by BOD, acute toxicity, chronic toxicity and release of contaminants of serious concern, including highly persistent, toxic fluorinated organic compounds. All reasonable and practical steps must be taken to manage and mitigate that risk. For firefighting foams it is now becoming clearer what constitutes the current state-of-knowledge and best practice regarding the management options, risks and potential impacts.

The *Managing Firefighting Foam* Policy takes into consideration the current state-of-knowledge as of November 2014 (including recognition of the gaps in that knowledge) to set out what is currently considered the basic environmental considerations and standards that need to be met by the suppliers and users of firefighting foam so that the user (who carries the bulk of the liability and risk) can achieve best practice and meet their obligations.

The Policy review and drafting process has taken into account the various and often competing considerations that the user faces in achieving a balanced and practical solution amongst the options available with compromises expected in some areas. Consideration has also been given to what constitute essential and reasonable standards and timelines for users to meet the Policy requirements.

9.1 General compliance timelines

PFOS-containing foams (including foams containing PFOS precursors) represent a very significant risk to human health and the environment. Users must determine if they have PFOS foams and if so they must be taken out of service immediately and disposed of properly. Where the origin or type of foam is in any doubt the user must undertake testing to determine its general composition against the Policy standards and take action accordingly.

Foams containing long-chain fluorinated organic compounds such as PFOA, PFOA precursors and higher homologues must be replaced as soon as practicable with a fluorine-free or C6-compliant foam. While this is being implemented interim measures must be put in place as soon as possible to prevent releases of foam to the environment. Note that new generation pure C6 foams must be fully contained, must not be discharged to the environment (including bodies of water, soils or groundwater) and any wastes must be properly disposed of.

9.2 Up to two years for large facilities to comply

Where significant changes to systems are required to come into compliance with the Policy and environmental legislation a period of *up to a maximum of two years* from the date of approval of the Policy is considered reasonable to implement such changes. Such changes must be made without undue delay within that period and the facility must be able to demonstrate that they can contain all releases from day-to-day activities and incidents in existing systems or by effective interim measures.

If there are justifiable reasons why changes cannot be carried out within two years then the operator of the facility can submit a set plan for regulatory approval under the available provisions of the state environmental legislation.

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