



Australian Government
Department of Defence



ADDENDUM DETAILED SITE INVESTIGATION REPORT SUMMARY - FORMER STOKES HILL NAVAL FUEL INSTALLATION SITE

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We would like to respectfully acknowledge the Larrakia people, the traditional custodians of Darwin, and also pay respect to Elders both past and present.

We would also like to pay our respects to the Indigenous men and women who have contributed to the defence of Australia in times of peace and war.

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INTRODUCTION

Senversa Pty Ltd (Senversa) has been engaged to deliver an environmental investigation at the former Stokes Hill Naval Fuel Installation site (Stokes Hill site) in Darwin, Northern Territory.

The objective of the environmental investigation is to understand the environmental health of the Stokes Hill site.

To do this, we have to identify the type and extent of contamination on the Stokes Hill site and any hazards and risks to people and the environment.

The Stokes Hill environmental investigation has been completed. It included the following stages:

1. *Preliminary Site Investigation.*
2. *Detailed Site Investigation (Dry Season sampling).*
3. *Addendum Detailed Site Investigation (Wet Season sampling).*

SUMMARY OF DETAILED SITE INVESTIGATION FINDINGS

The Detailed Site Investigation included a review of many historical reports and analysed data from sampling undertaken in the 2020 Dry Season.

It identified 19 source areas of contamination at Stokes Hill that were associated with the bulk storage and distribution of fuels and other chemicals at the site. These are shown on Figure 1.

The Detailed Site Investigation also confirmed that petroleum hydrocarbons (chemical compounds that contain hydrogen, carbon and other chemicals found in fuel) and PFAS (from legacy fire-fighting foam storage, distribution, and use) are the key contaminants at the Stokes Hill site.

Overall, the contamination identified was largely contained onsite at Stokes Hill.

Hydrocarbons were present in groundwater onsite but it was found that in general, hydrocarbon concentrations in groundwater have reduced or remained stable over time.

Concentrations of PFAS were found to be present across the site in soil, sediment, surface water and groundwater.

Offsite exposure risks through soil, sediment, surface water and groundwater were found to be unlikely.

The findings of the DSI and ADSI were that the site could be used for commercial / industrial use or as public open space (such as a park) provided some management measures are adopted.

ABOUT THE ADDENDUM DETAILED SITE INVESTIGATION

The Addendum Detailed Site Investigation sampling was undertaken in the 2021 Wet Season.

The Addendum Detailed Site Investigation report built upon the Detailed Site Investigation findings and closes out data gaps from the previous 2020 Dry Season works.

This additional investigation was needed to:

- Further confirm the nature and extent of contamination.
- Help to understand the differences between the Dry and Wet Season movement of contaminants in the environment.
- Confirm there are no unacceptable risks to humans, plants and animals and confirm if a Human Health and Ecological Risk Assessment needs to be carried out.

TYPES AND SOURCES OF CONTAMINATION

The Addendum Detailed Site Investigation Report includes assessment of:

Petroleum hydrocarbons

These are chemical compounds that contain hydrogen, carbon and other chemicals that are found in fuel. They can be released to the environment through accidents, leaks and spills or as by-products from industrial activities.

Heavy metals

Industrial sites such as Stokes Hill have the potential to contribute heavy metals, such as copper, zinc and lead, to the environment.

Per and Poly-Fluoroalkyl Substances (PFAS)

PFAS are man-made chemicals used in products that resist heat, oil, stains and water. The chemicals have been used around the world in many common household products and industry. Firefighting foams containing PFAS were once used and stored at the Stokes Hill site.

The Detailed Site Investigation found petroleum hydrocarbons and PFAS are the key contaminants at the Stokes Hill site.

SOURCES, PATHWAYS AND RECEPTORS

The Addendum Detailed Site Investigation Report identifies and analyses potential contamination sources, pathways and receptors.

Sources: where contaminants were stored, spilled or used.

Secondary sources: where contaminants have leaked or spilled onto a surface.

Pathways: the ways in which contaminants move through the ground and water.

Receptors: plants, animals and humans that may come into contact with the contaminants.

SUMMARY OF POTENTIAL RISK TO HUMANS AND THE ENVIRONMENT

As part of the Detailed Site Investigation Report, an initial assessment of risk from contamination to human health, animals and the environment was done.

This looked at sampling results and compared the results with published guideline values relevant to the humans, plants and animals that may come into contact with the contaminants.

The results of this showed a site specific Human Health and Ecological Risk Assessment was not required, but that this would be confirmed as part of the Addendum Detailed Site Investigation.

The Wet Season Addendum Detailed Site Investigation has confirmed:

- Offsite exposure risks to humans and the environment are unlikely.
- There are no known groundwater users within 500 metres of the Stokes Hill site.
- Contact with surface water may occur offsite, but the potential risk from this has been confirmed to be low.
- The offsite risk from surface water and sediment, including Frances Bay / Darwin Harbour, is better understood as a result of the Wet Season sampling and is confirmed as being low. The Stokes Hill site does not appear to be a significant contributor to contamination in Frances Bay as only some of the groundwater onsite moves offsite in the Wet Season.

The Addendum Detailed Site Investigation (Wet Season) confirms the Dry Season finding that no unacceptable human health or ecological risks have been identified.

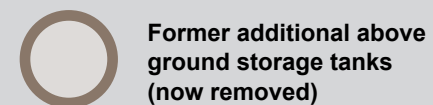
As a result, further detailed assessment of human health or ecological risk is not required.

The pages to follow show the results and analysis of the 2021 Wet Season sampling carried out as part of the Addendum Detailed Site Investigation.

POTENTIAL CONTAMINATION SOURCE AREAS

Potential contamination source areas

1. Former mobile aviation fuel storage tank
2. Maintenance shed
3. Hazardous goods store
4. Stormwater retention pond 1
5. Tanker loading and washdown bay
6. Main pump house and transformer
7. Stormwater retention pond 2 and triple interceptor trap
8. Stormwater retention pond 3
9. Removed hydrocarbon impacted soil
10. Former drum storage area
11. Former waste oil storage tank
12. Firefighting foam storage and former fire suppressant system
13. Former shed and new fire suppressant system
14. Firefighting foam storage shed
15. Firefighting foam storage shed
16. Open unlined drainage channel
17. Former caretaker's residence
18. Septic tanks
19. Shipping containers and laydown area



Addendum Detailed Site Investigation summary

Overall, the Addendum Detailed Site Investigation confirmed Detailed Site Investigation findings: that petroleum hydrocarbons (found in fuel) and PFAS (from firefighting foam storage and use) are the key contaminants at the Stokes Hill site.

The Wet Season sampling also showed:

- There is increased groundwater and surface water movement at the Stokes Hill site during the Wet Season compared to the Dry Season.
- While this increased volume of water leads to greater contaminant movement, potential impacts were found to remain largely unchanged. For example, PFAS concentrations in groundwater were found to be significantly lower across the site in the Wet Season.
- The movement of contaminated groundwater to the coast is limited during the Dry season and increases in the Wet Season. However, Wet Season groundwater flows show only a portion of the groundwater from the site enters Frances Bay.
- Offsite surface water impacts continue to be assessed as low.

Figure 1: Stokes Hill site boundary, Investigation Area, identified potential contamination source areas and the locations of former above-ground storage tanks and other infrastructure on adjacent land

GROUNDWATER SAMPLING RESULTS



Groundwater sampling results

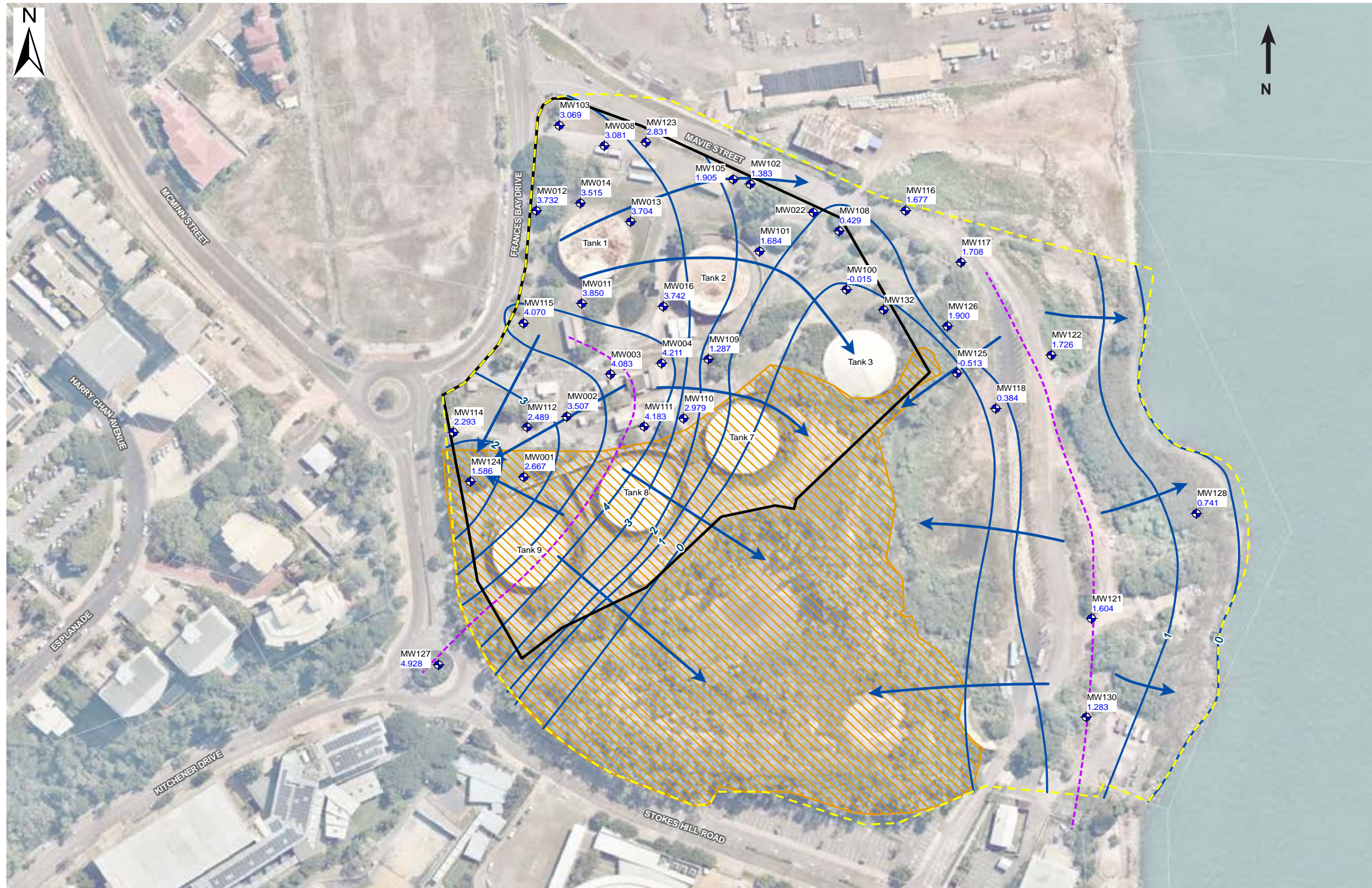
Thirty-five monitoring wells were sampled in the Wet Season.

- Hydrocarbon impacts in groundwater were generally limited to onsite with the highest concentrations associated with source area 16 (open unlined drainage channel).
- Increases in hydrocarbon concentrations in groundwater were found in several wells onsite and are likely to be the result of changes in groundwater flow direction and the higher water table in the Wet Season reaching hydrocarbon impacted soils.
- The highest hydrocarbon concentrations found offsite were to the northeast and southwest of the site.
- Onsite, PFAS in groundwater was widespread and concentrations were reported above the limit of reporting in all groundwater monitoring wells. The highest concentrations in groundwater onsite were at source areas 15 (fire fighting foam storage and former fire suppressant system) and 10 (former drum storage area).
- Compared to the Dry Season, PFAS concentrations are diluted in the Wet Season due to rain and a higher volume of groundwater.
- Similar to the 2020 Dry season, the majority of offsite wells contain PFAS concentrations significantly lower than those found onsite.
- Risks associated with metals, PFAS and hydrocarbon impacts in groundwater continue to be assessed as low and acceptable based on no groundwater extraction occurring onsite or in nearby offsite areas and the low availability and variable salinity of the groundwater.

Stokes Hill site boundary
 Investigation Area boundary
 Indicative Sacred Site boundary
 Potential contamination source area
 Groundwater monitoring well

Figure 2: Onsite and offsite groundwater sampling locations and key potential contamination source areas

GROUNDWATER FLOW DIRECTIONS AND CONTOURS - DRY SEASON



Groundwater flows and contours - Dry Season

The Dry Season sampling identified localised groundwater depressions, divides and reversals of flow direction.

These different directions of groundwater flow can be seen on Figure 3.

A large groundwater depression underneath the Sacred Site stops the majority of groundwater from the Stokes Hill site from entering the sea in the Dry Season.

The groundwater table is much lower in the Dry Season and rises significantly in the Wet Season.

Legend

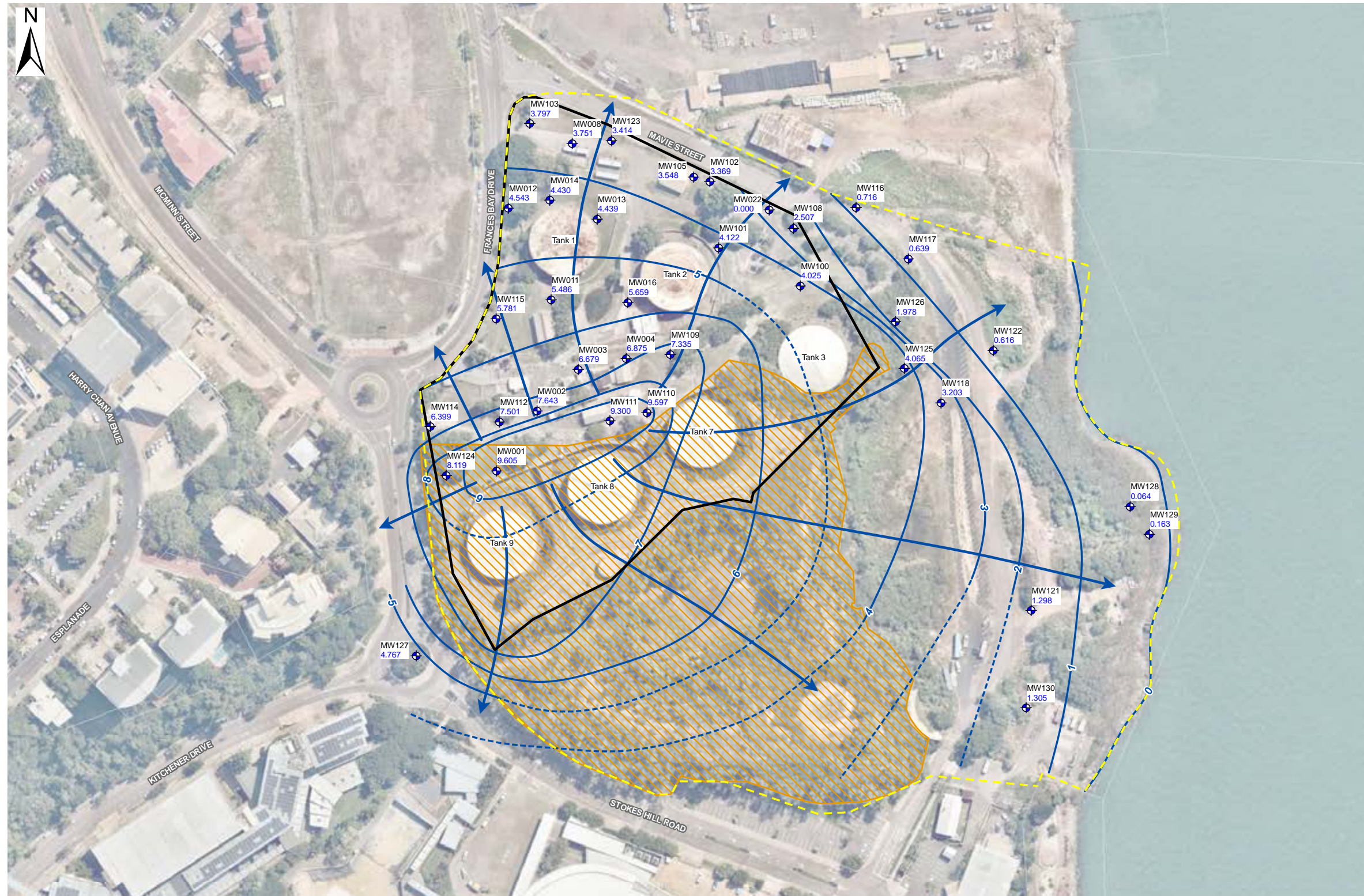
Groundwater Divide	Site Boundary
Inferred Groundwater Contour	Investigation Area
Groundwater Flow Direction	Sacred Site Boundary
Groundwater Monitoring Well	Lot Boundary

Well ID
Reduced Water Level (m AHD)

Notes:
Aerial imagery (08/05/2020) sourced from Nearmap Pty Ltd

Figure 3: Groundwater flow directions and contours - Dry Season

GROUNDWATER FLOW DIRECTIONS AND CONTOURS - WET SEASON



Groundwater flows and contours - Wet Season

The localised groundwater depressions, divides and reversals of flow direction that are present in the Dry Season disappear in the Wet Season.

This is due to an increased volume of water and the water table being much higher.

While this increased volume of water leads to greater contaminant movement, potential impacts were found to remain largely unchanged.

While more groundwater from the Stokes Hill site enters Frances Bay in the Wet Season than the Dry Season, groundwater flows show that it is only a portion of the groundwater from the site.

As can be seen on Figure 4, the Wet Season groundwater flows in a radial pattern in all directions from the site to offsite areas.

Legend	
Wet Season	
Inferred Groundwater Contour	Site Boundary
Estimated Groundwater Contour	Investigation Area
Inferred Groundwater Flow Direction	Sacred Site Boundary
Groundwater Monitoring Well	Lot Boundary
Well ID	
Reduced Water Level (m AHD)	
Notes: Aerial imagery (08/05/2020) sourced from Nearmap Pty Ltd	

Figure 4: Groundwater flow directions and contours - Wet Season

STOCKPILE, SEDIMENT AND SURFACE WATER SAMPLING RESULTS - WET SEASON



Stockpile, surface water and sediment sampling results

Stockpile

A stockpile on the northern site boundary was sampled. All materials identified were below both human health and ecological criteria with no asbestos detected. The stockpile location is shown on Figure 5.

Surface water

Six surface water samples were collected from onsite stormwater retention ponds and the open unlined drainage channel to the west of the site. Five surface water samples were collected from Frances Bay.

- Onsite, hydrocarbon impacts and metals including aluminium, arsenic, copper, lead and zinc were found in the open unlined drainage channel (source area 16) and retention ponds (source areas 4 and 7).
- Offsite surface water samples collected from Frances Bay contained exceedances of the 95 % protection marine ecological guidelines for arsenic and copper.
- PFAS were detected in all surface water samples onsite and in two surface water samples from Frances Bay. It is difficult to determine whether PFAS in Frances Bay are from the Stokes Hill site and / or from other sources.
- Offsite surface water sampling results remained consistent across the Wet and Dry Seasons and offsite impacts to surface water continue to be assessed as low. Onsite surface water is only present occasionally during the Wet season and was assessed as a low risk to plants and animals.

Sediment

Six sediment samples were collected onsite from the retention ponds (source areas 4 and 7) and the drainage channel (source area 16) in the Wet Season.

- There were no exceedances of guidelines for hydrocarbons in sediments.
- Metal impacts onsite were limited to copper in retention pond 1 and zinc in retention ponds 1 and 2 and the drainage channel.
- In the Dry and Wet Seasons, PFAS impacts were widespread onsite, with the highest concentrations reported in the drainage channel and retention pond 1. The potential for exposure for future sensitive uses is considered to be low.

Five sediment samples were collected from Frances Bay in the Wet Season. There were no detections of PFAS or hydrocarbons in the samples. No samples were collected from Frances Bay in the Dry Season.



Figure 5: Surface water and sediment samples and key potential contamination source areas

KEY DATA GAPS - ADDENDUM DETAILED SITE INVESTIGATION RESULTS

The Detailed Site Investigation helped us to better understand contamination at the Stokes Hill site, potential movement of contamination and the potential exposure risks to humans and the environment although some data gaps remained.

These have been closed as a result of the work that has been done as part of the Addendum Detailed Site Investigation.

Below are the data gaps identified in the Detailed Site Investigation and a description of how they have been closed.

1. ***What was the extent of use and storage of hydrocarbons, legacy fire-fighting foam and other chemicals within and in the vicinity of the Stokes Hill site and the locations of leakages, spillages and releases?***
 - The extent of usage, storage and locations where legacy fire-fighting foam, hydrocarbons and other chemicals were potentially stored and released is well understood.
 - This data gap is closed.
2. ***Are there sources, besides the identified source areas, that may be contributing to the contamination on the Stokes Hill site?***
 - Contamination source areas are well understood and have not changed as a result of the Wet Season sampling.
 - This data gap is closed.
3. ***Are the soils and concrete infrastructure beneath the identified sources contributing to impacted groundwater beneath the Stokes Hill site (and other associated risks)?***
 - Soil sampling indicates there is low potential for soil to be a secondary source of hydrocarbon contamination in groundwater.
 - All concrete samples contained PFAS and this may be a source of groundwater contamination - but this can be managed.
4. ***Are the soils across the Stokes Hill site contributing to the contamination and have these been adequately assessed?***
 - This data gap is closed.
 - The extensive soil sampling together with groundwater sampling means the levels and types of contamination in soil and potential impacts are well understood.
 - Given the depth to groundwater is shallow, especially during the Wet Season, it is likely that the concentrations in soil are contributing to hydrocarbons and PFAS in groundwater.
 - Concentrations of hydrocarbons, PFAS and metals (lead and zinc) in soil are present across the Stokes Hill site. This would need to be considered in future land uses.
 - This data gap is closed.
5. ***Is unexploded ordnance present within soils and sediments beneath the Stokes Hill site as a result of air raids that occurred during the Second World War?***
 - Sampling locations were surveyed by a specialist unexploded ordnance contractor. No unexploded ordnance was found.
 - Areas under tanks, buildings and pipes were generally not investigated for unexploded ordnance.
 - This data gap is closed.
6. ***Does soil vapour associated with the fuel tanks pose an unacceptable risk to the future users of the Stokes Hill site?***
 - Overall, the risk of vapour intrusion from hydrocarbons for residential and commercial properties is assessed as low and acceptable both onsite and offsite.
 - Inspection of residential properties near the site did not identify any properties with basements where vapour intrusion could be a risk.
 - It is understood that basements are likely to be present in the Darwin Convention and Exhibition Centre and Waterfront Development, and that vapour risks to properties in this precinct are already managed.
 - This data gap is closed.

7. What effects do the dry and wet season tides have on groundwater levels and flow direction at the Stokes Hill site and the surrounds?

- The Addendum Detailed Site Investigation has confirmed there is a significant difference in groundwater movement between the Wet and Dry Seasons.
- While more groundwater from the Stokes Hill site enters Frances Bay in the Wet Season than the Dry Season, groundwater flows show that it is only a portion of the groundwater from the site.
- This data gap is closed.

8. What is the direction of groundwater flow and is groundwater within the different geological units connected?

and

9. What is the lateral and vertical extent of affected groundwater at the Stokes Hill site and are the contaminant pathways understood?

- The Dry Season sampling identified localised groundwater depressions, divides and reversals of flow direction. The majority of groundwater flow is inward towards the site.
- These disappear in the Wet Season due to the increased volume of water and the water table being much higher. The majority of groundwater flows outward in all directions from the site.
- While this increased volume of water leads to greater contaminant movement, potential impacts were found to remain largely unchanged and the majority of contamination remains onsite in groundwater.
- For example, PFAS concentrations in groundwater were found to be significantly lower across the site in the Wet Season.
- Contaminant pathways from groundwater flow show that only a portion of the groundwater from the site enters Frances Bay in the Wet Season.
- These data gaps are closed.

10. Do shallow groundwater and surface water at the Stokes Hill site mix?

- The Detailed Site Investigation closed this data gap.
- The three retention ponds onsite fill when there is significant rain and if not topped up by more rain, are found to be mostly empty within three days. The ponds are unlined and contain deep mud cracks. This demonstrates surface water moving down into groundwater.

- Shallow groundwater could be mixing with surface water in the unlined drainage channel on the western side of the Stokes Hill site.
- This data gap is closed.

11. How does saline water from Darwin Harbour and fresh water beneath the Stokes Hill site interact?

- A saline wedge extends from the coast underneath the Investigation Area. A layer of fresh water sits over the saline wedge, which is recharged during the Wet Season and reduces in the Dry Season.
- The Wet Season sampling confirmed this finding.
- This data gap is closed.

12. Is contamination moving offsite through groundwater migration and/or surface water runoff?

- It is now confirmed that in the Dry Season, a large groundwater depression underneath the Sacred Site is stopping the majority of groundwater from the Stokes Hill site from entering the sea.
- The majority of groundwater discharge to Frances Bay occurs in the Wet Season. However, groundwater flows show only a portion of the groundwater from the site enters Frances Bay.
- In the Wet Season, PFAS were detected in all surface water samples onsite and in two surface water samples collected from Frances Bay. It is likely there are numerous other sources of PFAS entering Frances Bay.
- Offsite surface water sampling results remained consistent across the Wet and Dry Seasons and offsite impacts to surface water continue to be assessed as low.
- There is an underground stormwater pipe that travels in an unknown direction offsite. The continuation of this stormwater pipe could not be found beyond Mavie Street.
- This data gap is closed.

13. Are sediments/surface soils within and near the site contaminated and have these been adequately assessed?

- PFAS impacts in sediment onsite were widespread across both the Wet and Dry Season sampling. Although the risk to humans, animals and plants onsite is low, sediment can be transported offsite.

- There were no exceedances of guidelines for hydrocarbons in sediments.
- There were no exceedances or detections of PFAS or hydrocarbons in sediment samples collected from Frances Bay during the 2021 Wet season.
- Soils were adequately assessed as part of the Detailed Site Investigation.
- This data gap is closed.

14. What are the main migration pathways and sources, such as drainage lines, stormwater retention ponds and stormwater networks and have these been sufficiently assessed?

- An underground stormwater pipe leaves the site to the north.
- The retention ponds are sealed off at the site boundary and water cannot leave site from the ponds.
- Offsite surface water sampling results remained consistent across the Wet and Dry Seasons and offsite impacts to surface water continue to be assessed as low.
- This data gap is closed.

15. What are the offsite human and ecological receptors that may come in contact with impacted groundwater, surface water and sediments and have these been sufficiently assessed?

- It has been confirmed that the Stokes Hill site does not present a risk to offsite human and ecological receptors that may come in contact with impacted groundwater, surface water and sediments.
- This data gap is closed.

16. What is the typical soil, groundwater and surface water quality of the surrounding area so that other potential contamination source areas can be understood?

- Soil sampling was undertaken at sampling locations along the Stokes Hill site boundary and offsite to the northeast and east to assess potential up gradient sources of soil contamination.
- Soil samples to the northeast and east contained PFAS. Samples collected along the eastern boundary contained metals.
- The long history of industrial facilities in the area has likely contributed to contamination in soil and groundwater the surrounding areas.
- Groundwater wells installed upgradient have supported the understanding of the complex hydrogeology at the site.
- In the Wet Season, PFAS were detected in all surface water samples onsite and in two surface water samples collected from Frances Bay. It is likely there are numerous other sources of PFAS entering Frances Bay given only a portion of groundwater from the site enters the Bay in the Wet Season only.
- There is a long history of sampling the offsite areas. The sampling over the years has shown that concentrations of hydrocarbons and PFAS have decreased or remained the same.
- This data gap is closed.

SUMMARY AND NEXT STEPS

The Addendum Detailed Site Investigation confirmed Detailed Site Investigation findings: that petroleum hydrocarbons and PFAS (from firefighting foam storage and use) are the key contaminants at the Stokes Hill site.

The Wet Season sampling showed:

- Increased groundwater and surface water movement at the Stokes Hill site during the Wet Season compared to the Dry Season.
- While increased volume of water leads to greater contaminant movement, potential impacts remain largely unchanged with PFAS concentrations in groundwater lower across the site in the Wet Season.
- The movement of contaminated groundwater to the coast is limited during the Dry season and increases in the Wet Season.
- Overall, the proportion of groundwater from the site flowing into Frances Bay remains negligible.
- Offsite surface water sampling results remained consistent across the Wet and Dry Seasons and offsite impacts to surface water continue to be assessed as low.

The Addendum Detailed Site Investigation confirms the findings of the Detailed Site Investigation (Dry Season), concluding that no unacceptable human health or ecological risks have been identified for ongoing industrial/commercial use or parkland with management measures.

Further detailed assessment of human health or ecological risk is not required.

No further environmental investigation is required to enable Defence to start the divestment process.

Defence will continue to engage with the Northern Territory Government about the potential future use and divestment of the site.