Canine Oil Detection: Field Trials Report

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EXECUTIVE SUMMARY

Field trials sponsored by the American Petroleum Institute (API) were conducted in February 2020 using three oil detection canines at a canine training center near San Antonio, TX. The focus of the trials was to evaluate a canine's ability to detect weathered and heavy oils and to ascertain if the canines could detect those target oils buried at depths up to 15 feet (5 m).

The oils used in the tests were, in order of increasing viscosity;

- unweathered dilbit,
- unweathered Bunker C fuel,
- weathered Macondo crude oil ("CTC"),
- very weathered semi-solid Macondo crude oil ("Juniper"), and
- solid tar balls from a mat collected on a beach at Mustang Island, TX.

Initially a set of tests was conducted with each oil and each canine using a carousel in an indoor environmentally controlled room. All of the indoor tests were run "double blind": that is, neither the canine nor the handler was in the room when the targets were placed in the carousel. There were thirty-eight (38) runs in this initial test, including three (3) blank runs (one for each canine). Below is a summary of the results:

- No oil targets were missed as the canines correctly responded on all thirty-eight (100%).
- Four (4) false positives were documented, all by the youngest and least experienced canine:
    - three "false" alerts were prior to the correct response on the canine's first run after the blank set whilst searching for the very weathered tar ball target; and
    - one "false" alert was prior to the correct response during the second run on a search for the Bunker C target.

A Wide-Area Survey (WAS) field test was conducted with an array of 15 foot- (5-m) length vertical pipes distributed throughout a grassy field. Pipes were either empty, contained blanks of native soil, or contained one of the oiled targets at the base of the pipe under native soil. The sediments in the pipes were the backfill of native soil drill cuttings that were created from the pipe placement. The environmental conditions for the field tests were cool (50 to 60°F) with steady winds between 1.5 and 4 miles/hour, gusting to 6 miles/hour.

- The dilbit, Bunker C, and tar ball targets had been placed in the pipes one week prior to the tests. The two Macondo weathered oils were placed less than 24 hours prior to the tests.
- During five (5) runs over the array the canines detected the odor plumes from the oil target pipes whilst quartering the field and followed the odor directly to the source; in several cases a plume was detected from distances up to 100 feet (30 m) from the source when working into the wind.
- Twenty (20) of the twenty-one (21) oil targets were correctly detected and all twenty-nine (29) blank target or empty pipes were disregarded for a success score of 49 out of 50 targets (98%).
- One target, the very weathered semi-solid Macondo "Juniper" oil, was not detected by one of the canines but was detected by the other two.

Two (2) tests were run over an array of 5-feet (1.5-m) deep targets with 100% success. Other planned tests using 1-foot, 2-feet, and 3-feet (30-cm, 60-cm, and 90-cm respectively) deep targets were not run after the canines had already successfully detected all of the deeper 15-feet and 5-feet targets.

Measurements at each target were taken with a high-sensitivity Photo-Ionization Detector (PID) following each indoor and field canine test.

- The PID did not detect the oils in the carousel using the same set up as the canine tests (with the perforated container lid in place) and with the sample port held within 1 inch (2 cm) of the lid. When the lids were removed and the sample port was placed and held stationary inside the container, the PID detected five (5) of the six (6) oil targets; no reading was registered for one of the two tar ball targets.
- Following the field test with the 15-foot (5-m) pipe array, the PID only registered VOCs when the sample port was placed and held stationary inside the pipe <1 inch (2 cm) from the surface of the sediment. In these circumstances, VOCs were detected on five (5) of the eight (8) oil target pipes; the non-detects were on both runs over the pipe that contained the tar ball target and on the second run over the dilbit target. VOCs were detected on each of the four (4) oil targets in the shallower depth 5-ft (1.5-m) array under the same stationary sampling circumstances.

The results of the study provide conclusive proof that, even in the cooler temperatures (50-60°F) at the time of the trials, the canines are able to quickly and accurately detect heavy (Bunker C) and very weathered oils (Macondo “Juniper” and tar balls) at a depth of 15 feet (5 m), as well as the other two oil targets (the unweathered dilbit and partially weathered Macondo “CTC” oils).

The canines demonstrated a working survey speed in the range of 4 to 6 miles/hour (7 to 10 km/hour) and a coverage rate of 13 acres/hour (5 hectares/hour). The survey speed associated with the use of the hand-held PID was considerably slower and VOC detection required placing the sample port stationary and very close (1 inch: <2 cm) above the open target jar with the steel pot lid removed for the indoor tests and less than ½ inch (1 cm) above the soil surface in the field tests. The PID only detected VOCs when held stationary and close to the target surface. The PID did not detect VOCs on one of the tar ball targets during the indoor runs and during the 15-feet (5-m deep) target WAS field runs did not detect on either of the two tar ball runs and one of the two dilbit runs.

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1 Introduction

The Science and Technology Working Group of the American Petroleum Institute (API) Joint Industry Task Force (JITF) Oil Spill Preparedness and Response program has funded several studies to review subsurface oil detection techniques (API 2013a, 2013b, 2014, 2016b) and to evaluate the performance of canines to detect subsurface oil in a set of 2015 field trials (API 2016a). The use of canines to detect surface and subsurface oil was initiated in Norway in the late 2000's (Brandvik and Buvik, 2009; Owens and Bunker, 2020). Building on this pioneering work, the results of the 2015 field trials demonstrated that a canine oil survey team is a realistic and practical option to support Shoreline Cleanup Assessment Technique (SCAT) assessment surveys and other spill response and leak detection applications. Canine teams can be deployed with confidence for the rapid detection and delineation of subsurface oil and offer a non-labor-intensive alternative to traditional survey options in a range of coastal and inland oil spill conditions.

Following the 2015 API study, field surveys with detection canines were conducted in Nova Scotia on the 2015 T/V *Arrow* release (Owens *et al*., 2017) and in 2016 in northern Prince William Sound, Alaska (Owens *et al*., 2018). Multiple canine survey teams were deployed operationally in 2016, 2017 and 2018 to support a river spill response on the North Saskatchewan River (Owens and Reimer, 2018).

2 Objectives

The primary objective of the 2020 API studies was to address three key uncertainties that previously had not been investigated and specifically to address the following questions:

- Are canines able to detect heavy or weathered oil (that has low to very low volatile organic carbon content)?
- Are canines able to detect oils at greater depths than previously tested (36" - 90 cm)?
- Can a canine be trained to indicate only when oil concentrations are greater than a certain threshold (for example, 500 ppm)?

The first two questions were addressed during a set of trials conducted by Owens Coastal Consultants and Chiron K9 on 10-12 February 2020 at the facilities of the Global Training Academy (GTA) near San Antonio, TX. The third question was addressed by the Olfactory Research and Education Laboratory of the Department of Animal and Food Science Center at Texas Technical University (TTU), Lubbock, TX, during the first semester of 2020 and is reported separately (DeChant and Hall, 2020).

3 Test Preparation and Methods

3.1 Carousel Tests

A room specifically designed for canine tests at the GTA facility included a temperature-controlled environment with an industrial-size exhaust fan and a "viewing room". The room temperature was set at 68°F (20°C) for the tests.

Samples jars (4 oz. mason jars) were all prepared in the same manner. They were purchased specifically for this trial. All jars were washed in hot soapy water, then run through a cycle in a dishwasher including sanitation wash and heat dry. All the jars then had 2 oz. of native sand from the same location added. Two jars for each target had 2 ml of oil added before the native soil was placed on top. Jars were then stored in small plastic ammunition-type containers separated into those containing only native soil and those containing native soil with target. The ammunition cans were all purchased from the same location, washed and cleaned with acetone and air dried before being used for storage. All cans were stored in a freezer prior to the test (Figure 3.1).

Figure 3.1 Target storage

A carousel with 12 sample arms was centered in the test room (Figure 3.2). Each sample arm had a stainless steel pot at the end, in which the mason jars containing either native soil ("blank") or native soil with product ("target") were placed. For each test, 11 pots contained blank jars, and one pot contained a target jar. The stainless steel pots had perforated lids which had 0.1 inch (3 mm) holes in three circles, allowing 8% exposure to escaping vapor. One target jar, with the lid removed, was placed in a carousel arm while the canine and handler were outside the room to follow a "double blind" protocol. The three canines were tested separately for each product. After one canine was tested, the carousel was spun so that the target jar moved to a different location on the apparatus. After the tests with one oil, the target jar was removed, the carousel was cleaned with acetone, the room vented and then another oil target jar was placed. The technician wore disposable gloves whenever handling either the native soil only or the native soil and target jars/pots. Separate gloves were used to handle each type of jar/pot to prevent any cross-contamination of odors. Gloves were disposed of as soon as they had been used for one jar/pot.

Figure 3.2 Test room seen from the "viewing room" and close-up view of the carousel

During each test, the handler was positioned by the door and gave no direction or communication to the canine other than to "search". Once the canine had alerted to a target the handler and canine left the room and the canine was rewarded.

Each run by a canine was documented by an observer in the viewing room on a specially created form (Attachment C: Carousel Score Sheet) and each run was videotaped.

3.2 Field Site Tests

3.2.1 Wide Area Search Tests

A large open grassy field within the GTA training facility grounds was made available for the Wide Area Search (WAS) trials (Figure 3.3). Ten holes were drilled by a mechanical auger at an offset spacing of 100-feet (30-m) (Figure 3.4). The design was intended to represent a Right-of-Way (ROW) corridor for a buried pipeline and the resulting search area was approximately 130 feet (40 m) wide and 425 feet (130 m) in length; that is, on the order of 1.27 acres (0.52 hectare).

A 15-foot (5-m) 6-inch PVC "outer" pipe was placed within each hole. The pipes were not sealed at the bottom so that water could drain through. The cuttings were side cast in order to fill the inner 4-inch pipes at a later time. An approximate 24-inch long plug of native soil was positioned and packed at one end of the "inner" 4-inch pipes.

During the field trials, three (3) of the pipes were empty on the first day and one (1) on the second day as two pipes were loaded with oil targets after the first set of trials. Four (4 pipes) were filled with native soil as "blank targets" (see Attachment B).

Figure 3.3 Global Training Academy (GTA) field test areas, Somerset, TX

Figure 3.4 Wide Area Search (WAS) field 15-foot (5-m) depth pipe array

The oil target was placed against the bottom of the plug of native soil (Figure 3.5 left), and the 4" inner pipe was capped and sealed with pipe adhesive (Figure 3.5 right). The pipe was inserted in the "outer" pipe (Figure 3.6) and filled to the top with the side-cast native soil.

Figure 3.5 Weathered Macondo ("Juniper)" oil placed and sealed at the bottom of a 15-foot (5-m) pipe

Figure 3.6 Insertion of the 15-foot (5-m) inner pipe with loaded target

The dilbit, Bunker C, and tar ball targets were loaded and placed approximately one week before the trial (see Table 3.3 below). The pipes were prepared by an independent assistant and the locations of the targets were recorded and sealed in an envelope, so the canine handlers had no access to the target locations (Attachment B). Both of the WAS tests on the first day were run "double blind": that is, neither the canines nor the handler knew which pipes contained an oil target prior to the search.

The Macondo "CTC" and Macondo "Juniper" oils were loaded less than 24-hours prior to the test (Figures 3.5 and 3.6) and, as one of the handlers had assisted in the preparation of these two pipes, only one of the three runs on the second day (by canine "C") was double blind.

The five oil targets were left in place in the pipes for potential future use. The pipes were capped. One pipe (# 5 in Attachment B) was unused and has an empty inner pipe that was capped but with no soil.

3.2.2 Delineation Tests

Fifty (50) 2-inch internal diameter PVC "outer" tubes were buried in a 10 x 5 diagonal grid, spaced 15 feet (5 m) apart in the South Field Certification Area at the GTA facility (Figures 3.3 and 3.7). The five end tubes in this "certification grid" were 36" (90 cm) deep; the remainder were 24-inch (60 cm) deep. Six 12-inch (30 cm) and five 60-inch (1.5 m) tubes were buried outside the certification grid. All of these 61 "outer" tubes were open ended to allow drainage and prevent accumulation of rainwater. The placement of the targets followed the same procedure as described above for the WAS tests.

The field study design included use of all five test oils in these arrays in case the 15-foot (5-m) targets were not detected or those test runs were only partially successful. In the event, only the 5-foot (1.5-m) pipes were used in this part of the field trials as the shallower depth tests were considered unnecessary once each of the three canines had detected each of the five oils at 15-foot depths. Two of the 5-foot pipes were loaded less than 24-hours prior to the test using the Macondo "CTC" and Macondo "Juniper" oils (Table 3.3 below).

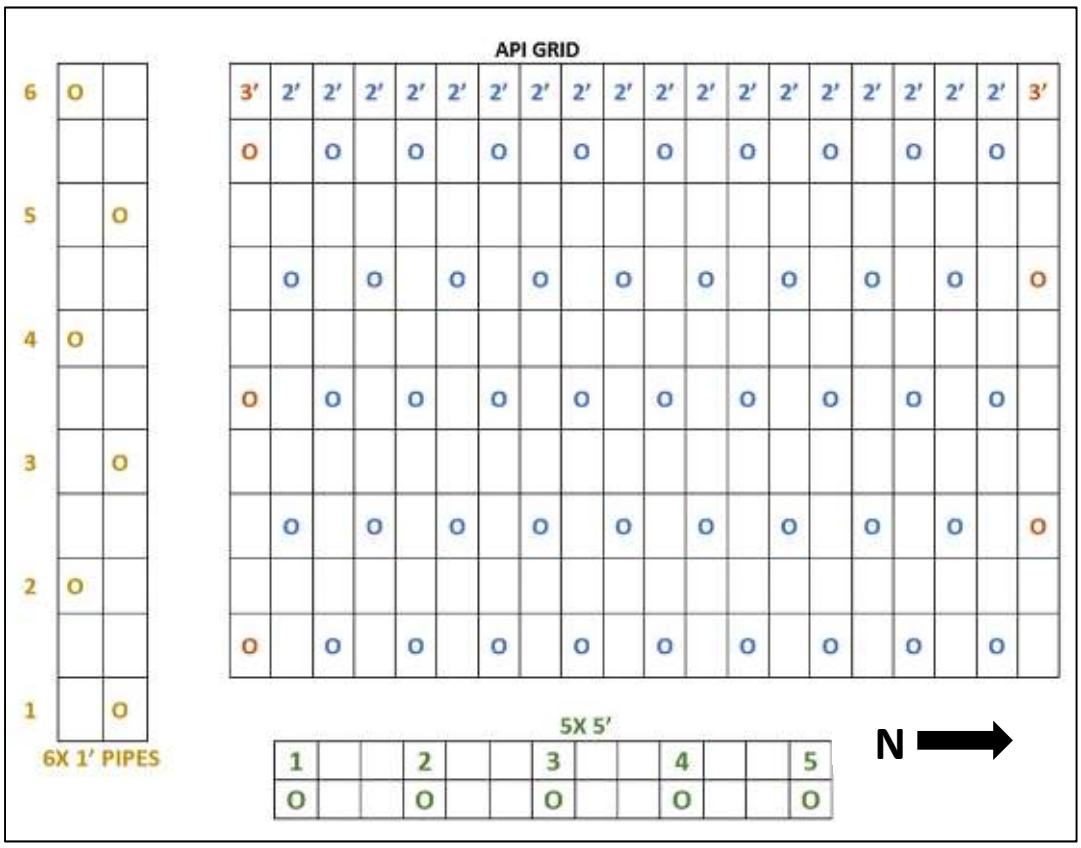

Figure 3.7 South Field Certification Area pipe array

3.3 Volatile Organic Compounds Detection

A commercially-available Photoionization Detector (PID) was used in order to determine whether the carousel and field targets could be detected by typical air monitoring methods. An Honeywell UltraRAE 3000+ (with no separation tube) was chosen for this project due to its high sensitivity to general volatile organic compounds (VOCs) and ease of use compared to other available PID instrumentation. This instrument is more sensitive than many other commonly used PIDs. The instrument was calibrated with fresh air and 5 ppm benzene prior to each test run (Attachment A). Table 3.1 provides the detection limits of the UltraRAE 3000+ for BTEX. It is important to note that we do not yet understand which components of the oils that the canines use for detection; however, it is understood that they may use more than one, and different canines may use different components.

Table 3.1 PID Detection limits for Select Constituents (BTEX and some straight chain alkanes)

Constituent	Correction Factor Calibrated to Benzene	Concentration to reach Detection Limit (ppm)
Benzene	1	0.0100
Toluene	0.99	0.0101
Ethylene	0.95	0.0105
Xylene, m-	0.91	0.0110
Xylene, o-	1.02	0.0098
Xylene, p-	0.87	0.0115
Pentane	145.45	0.0001
Hexane, n-	636.36	0.00002
Heptane	81.81	0.0001
Octane	23.64	0.0004
Decane	7.27	0.0014

3.4 Test Oils

The test oils that were selected by the API Working Group are listed and described in Table 3.2 in order of increasing viscosity. Gas chromatograms (GCs) representative of the Cold Lake dilbit, CTC and Juniper oils and actual GCs of the target Bunker C and tar ball oils used in these trials are provided in Attachment D. The volumes of the oils and the weight of the tar ball used in each carousel jar and pipe, as well as the dates installed, are provided in Table 3.3.

The unweathered dilbit was a fluid Cold Lake Crude Oil Blend and the release of light ends produced a strong odor when the oil was exposed. The Bunker C Fuel oil was unweathered and poured slowly. The two Macondo oils are considered similar in composition and “stage 3” weathered oils: that is, they had been attenuated by dissolution, evaporation and photodegradation, but not biodegradation (Cook *et al*. 2020). The two Macondo samples received for the trials had distinctly different viscosities: whereas the “CTC” oil had a reported viscosity around 6,500 cSt and poured slowly, the “Juniper” oil with an

estimated viscosity (NOAA 2015) of about 90,000 cSt had to be scraped from the container. The solid tar ball was shiny and black when broken; the oil contained no visible sediment.

Table 3.2 Test Oils

OIL TYPE	OIL CHARACTER
unweathered (Cold Lake) dilbit	very fluid
unweathered Bunker C fuel	viscous, slow pour, similar to syrup
weathered Macondo crude oil	highly viscous, poured very slowly, similar to cold honey
very weathered semi-solid Macondo crude oil	semi-solid, did not pour
tar balls from a mat collected on a beach at Mustang Island, TX	solid

Table 3.3 Amount and Dates of Product Loaded into Each Target

TEST OIL	DETAIL	TARGET TYPE					
		Jar	*1' pipe*	*2' pipe*	*3' pipe*	*5' pipe*	*15' pipe*
dilbit	**Volume**	**2 ml**	**10 ml**	**10 ml**	**20 ml**	-	**1 l**
	Date added	7-Feb-20	5-Feb-20	5-Feb-20	5-Feb-20	-	3-Feb-20
Bunker C	**Volume**	**2 ml**	**10 ml**	**10 ml**	**20 ml**	**0.25 l**	**1 l**
	Date added	7-Feb-20	5-Feb-20	5-Feb-20	5-Feb-20	4-Feb-20	3-Feb-20
Macondo crude – CTC	**Volume**	**2 ml**	-	-	-	**0.25 l**	**1 l**
	Date added	10-Feb-20	-	-	-	10-Feb-20	10-Feb-20
Macondo crude – Juniper	**Volume**	**2 ml**	-	-	-	**0.25 l**	**1 l**
	Date added	10-Feb-20	-	-	-	10-Feb-20	10-Feb-20
tar ball	**Weight**	**0.1 oz**	**0.1 oz**	**1.4 oz**	**2 oz**	-	**0.8 lb**
	Date added	7-Feb-20	7-Feb-20	7-Feb-20	7-Feb-20	-	3-Feb-20

3.5 Documentation

In order to document the conditions, results and observations of the field trials, project-specific forms were developed for both the indoor carousel and the field WAS tests. Since the carousel testing was a new process for the project team, the carousel forms also included instructions for setting up the carousel and recording the necessary information. The following blank forms are provided in Attachment C:

- Carousel Arm Contents: to document the contents of each arm for each test run, as well as the time each product was loaded.
- Carousel Score Sheet: to document the start and stop time of each test run, correct and false alerts, missed targets, and the type of alerts (sit, lay down, or "buzz") for each test run and canine.
- Canine Oil Detection Field Trial Survey Forms: SCAT-type field forms, to document the weather and field conditions, timing, alerts (correct, false, and missed), and other observations, similar to the forms developed for the 2015 API tests. A separate form was developed for each:
    - 15 ft (5m) pipe array
    - 5 ft (1.5m) pipe array
    - 2 and 3 ft (0.6 and 1m) pipe array
    - 1 ft (0.3m) pipe array

A portable meteorological station was set up to record near-ground wind, temperature, humidity and atmospheric pressure during the WAS tests (Table 3.4).

Table 3.4 Meteorological Data at the Time of the First and Last WAS Runs Each Day

Date	Time	Weather	Air Temp (°F)	Wind Direction	Wind Speed (mph)	Gusting (mph)	Humidity (%)	Pressure (in/hg)
2/11/2020	9:48	Cloudy	57	WNW	1.5	4.7	61	29.3
2/11/2020	10:08	Cloudy	48	WNW	3.6	7.6	83	29.3
2/12/2020	9:25	Cloudy	48	WNW	3.7	6.5	70	29.2
2/12/2020	13:34	Cloudy	62	WNW	3.5	4.9	68	29.2

3.6 Oil Detection Canines

Two trained Oil Detection Canines (ODCs) were used on both days and a third was available on the second day of the trials only. They were handled by professional canine handlers.

The trials were observational in nature and were not considered to be outside the normal realm of working dog training guidance. As such, the trials did not require review and approval by an Institutional Animal Care and Use Committee (IACUC) (NRC 2011; NIH 2019). The activities were conducted by professional handlers trained and certified in the care and ethical use of canines. Training methods for these ODCs, handler responsibilities, and handler certification are described by Bunker (2017) and ICSALDA (2019).

With respect to the capabilities of the canines used in these trials, Nika and Lily (Labradors) were field-deployed, experienced ODCs that had verified alerts during extended-period SCAT surveys on weathered oils. Poppy was a young English Springer Spaniel ODC that had just completed her initial training, with no field deployment experience and no previous exposure to heavy or weathered oils.

4 Field Trials

4.1 Carousel Tests Results

4.1.1 Canine Tests

Thirty-eight (38) runs were conducted during the indoor tests; these included three (3) blank runs (one for each canine). The results of the tests are summarized below and in Table 4.1.

- Each test took one (1) minute or less to complete by the canine.
- No oil targets were missed as the canines correctly responded on all thirty-eight (100%).
- Four (4) "false positives" were documented, all by the same canine ("B" – the youngest and least experienced; see Discussion in Section 5.1):
  - Three "false" alerts were recorded prior to the correct response on the canine's first run after the all-blank set whilst searching for the very weathered tar ball target; and
  - one "false" alert was prior to the correct response during the second run on a search for the Bunker C target.
  - Two additional alerts noted as "False Positives" (Juniper series) are not attributed to the canine but due to an experimental protocol lapse in which a container that had held a target product on a prior run was not cleaned with acetone before the next run, and therefore contained residual product odor.

Table 4.1 Results of Canine Carousel Tests

OIL	# Runs	# Targets	# Targets Hit	% Targets Hit	# Targets Missed	% Targets Missed	# False Positives	Comments
blank	3	0	0	*N/A*	0	*N/A*	0	Canine B hesitated at pot #2, no alert
dilbit	9	9	9	100%	0	0%	0	-
Bunker C	9	9	9	100%	0	0%	1	Canine B alerted at pot #9
CTC	2	2	2	100%	0	0%	0	-
Juniper	4	4	4	100%	0	0%	2*	Canine B first runs on Juniper
tar ball	11	11	11	100%	0	0%	3	Canine B first run after all blanks
TOTAL	**38**	**35**	**35**	**100%**	**0**	**0%**	**4**	**-**

* accidentally contaminated jar – not canine error

4.1.2 PID Tests

The PID did not detect VOCs with the sample port held within 1 inch (2 cm) of the lid of the pots in the carousel using the same set up as the canine tests (with the perforated container lid in place on the steel pot) (Table 4.2) (Figure 4.1). When the lids were removed and the PID sample port was placed inside the container the PID detected four (4) of the five (5) targets which registered VOC levels in the range of 0.2 to 3.3 ppm and detected the dilbit which registered at 53.5 ppm; no reading was registered on one of the two tar ball targets.

Figure 4.1 PID sampling of a carousel pot with the perforated lid on

Table 4.2 Carousel PID Readings ("lid off" readings in bold)

OIL	Date	Approx. Time	PID Reading (ppm VOC)
blank (vented pot lid on)	2/10/2020	10:20	0
tar ball (vented pot lid on)	2/10/2020	10:30	0
tar ball (**lid off**, PID inside jar)	2/10/2020	10:30	**0**
tar ball (vented pot lid on)	2/12/2020	12:00	0
tar ball (**lid off**, PID inside jar)	2/12/2020	12:00	**0.2**
Bunker C (vented pot lid on)	2/10/2020	11:30	0
Bunker C (**lid off**, PID inside jar)	2/10/2020	11:30	**3.3**
dilbit (vented pot lid on)	2/10/2020	12:00	0
dilbit (**lid off**, PID inside jar)	2/10/2020	12:00	**53.5**
Juniper (vented pot lid on)	2/12/2020	12:30	0
Juniper (**lid off**, PID inside jar)	2/12/2020	12:30	**0.5**
CTC (vented pot lid on)	2/12/2020	13:00	0
CTC (**lid off**, PID inside jar)	2/12/2020	13:00	**0.2**

4.2 Wide Area Search (WAS) Field Tests Results

4.2.1 Canine Tests

All WAS tests were conducted off-leash with the handler directing the canine search pattern. The canines detected the odor plumes while quartering the field and followed these plumes directly to the source from distances up to 100 feet (30 m) when working into the wind.

Five (5) runs on the 15-foot (5-m) pipe array were conducted in the WAS field trials. The results are summarized below and in Tables 4.3 and 4.4.

- Twenty (20) of the twenty-one (21) oil targets were correctly detected and all twenty-nine (29) of the blank target or empty pipes were disregarded for a success of 49 out of 50 (98%) (Table 4.3).
- One target, the very weathered semi-solid Macondo/"Juniper" oil on the second day, was not detected by one of the experienced ODCs but was detected by the other two canines. This run was not "double blind" as the handler had participated in the placing of that target on the previous day. Speculatively, a sub-conscious behavior change by the handler to not inadvertently "cue" the canine into a response could attribute this to handler error rather than a "miss" by the canine.
- One (1) "false positive" was recorded on 12 February in an area between pipes #5 and #7 by one canine and was investigated by the other two canines (Figure 4.2). This was considered to be an oil not associated with the tests and possibly related to the operation of the machinery during pipe installation.

The original WAS design included use of the South Field Certification Area pipe array (Section 3.2.2; Figures 3.3 and 3.7) with the five test oils, three of which had been loaded into the inner pipes approximately one week prior to the field trials. Two (2) of the 5-foot pipes were loaded with the Macondo "CTC" and Macondo "Juniper" weathered crude oils less than 24-hours prior to the test (Table 3.4). Only the 5-foot (1.5-m) pipes were used in this set of shortened field trials as the shallower depth tests were considered unnecessary once each of the three canines had previously detected each of the five oils at 15-foot depths. Two (2) tests were run over the 1.5-m (5-feet) depth targets with 100% success (Runs F6 and F7; Table 4.3). Further delineation-style tests were considered unnecessary also because the delineation capability of ODCs had been fully demonstrated in the 2015 field trials (API 2016a).

Each canine was fitted with a GPS unit on the collar to document time and location during each WAS run (Figure 4.2). All three canines searched at a similar working speed, between 5 and 6 mph (7.7 and 9.8 km/hour) (Table 4.4). Each run covered the approximately 1.27 acres (5,200 m^2; 0.52 hectares) search area in less than 6.25 minutes and in one run as quickly as 3.7 minutes. Other field surveys have provided similar canine track line survey speeds of 3 to 6 miles/hour (5 to 10 km/hour) depending on the terrain character (Owens *et al*., 2018; Owens *et al*., 2017).

Table 4.3 Results of Canine WAS Tests

Run	Date	Canine	Target Depth (ft/m)	# Empty Pipes	# Blank Targets	# Oil Targets	# Dilbit Hits	# Bunker C Hits	# Tar Ball Hits	# Juniper Hits	# CTC Hits	# Total Targets	# Total Correct	# Total Misses	% Targets Detected	# False Positives
F1	2/11/2020	A	15 / 5	3	4	3	1	1	1	N/A	N/A	10	10	0	100 %	0
F2	2/11/2020	B	15 / 5	3	4	3	1	1	1	N/A	N/A	10	10	0	100 %	0
F3	2/12/2020	C	15 / 5	1	4	5	1	1	1	1	1	10	10	0	100 %	1 *
F4	2/12/2020	A	15 / 5	1	4	5	1	1	1	0	1	10	9	1 *	90 %	0
F5	2/12/2020	B	15 / 5	1	4	5	1	1	1	1	1	10	10	0	100 %	0
F6	2/12/2020	A	5 / 1.5	2	0	3	N/A	1	N/A	1	1	5	5	0	100 %	0
F7	2/12/2020	B	5 / 1.5	2	0	3	N/A	1	N/A	1	1	5	5	0	100 %	0
TOTAL 15 ft (5 m) pipes				*9*	*20*	*21*	*5*	*5*	*5*	*2*	*3*	*50*	*49*	*0*	*98 %*	*1*
TOTAL 5 ft (1.5 m) pipes				*4*	*0*	*6*	*0*	*2*	*0*	*2*	*2*	*10*	*10*	*0*	*100 %*	*0*
TOTAL all pipes						***27***	***5***	***7***	***5***	***4***	***5***	***60***	***59***	***1***	***98.3 %***	***1***

* see text

Table 4.4 Canine Time and Distance Search Data on the 15-foot (5-m) Deep Targets

Run #	Pipe Depth (ft / m)	Date	Canine	Search Track Line (m)	Total Survey Time (min:sec)	Actual Search Time (min:sec)	Ave. Survey Speed (kph)	Ave. Search Speed (kph)	Max. Search Speed (kph)
F1	15 / 5	2/11/2020	A	858	6:52	5:13	7.6	9.8	24.1
F2	15 / 5	2/11/2020	B	864	7:45	6:16	6.8	8.2	22.5
F3	15 / 5	2/12/2020	C	475	4:50	3:41	6.0	7.7	19.3
F4	15 / 5	2/12/2020	A	663	6:15	4:23	6.4	9.0	22.5
F5	15 / 5	2/12/2020	B	631	6:07	4:28	6.1	8.5	22.5
AVERAGE				***698***	***6:22***	***4:48***	***6.6***	***8.7***	***22.2***

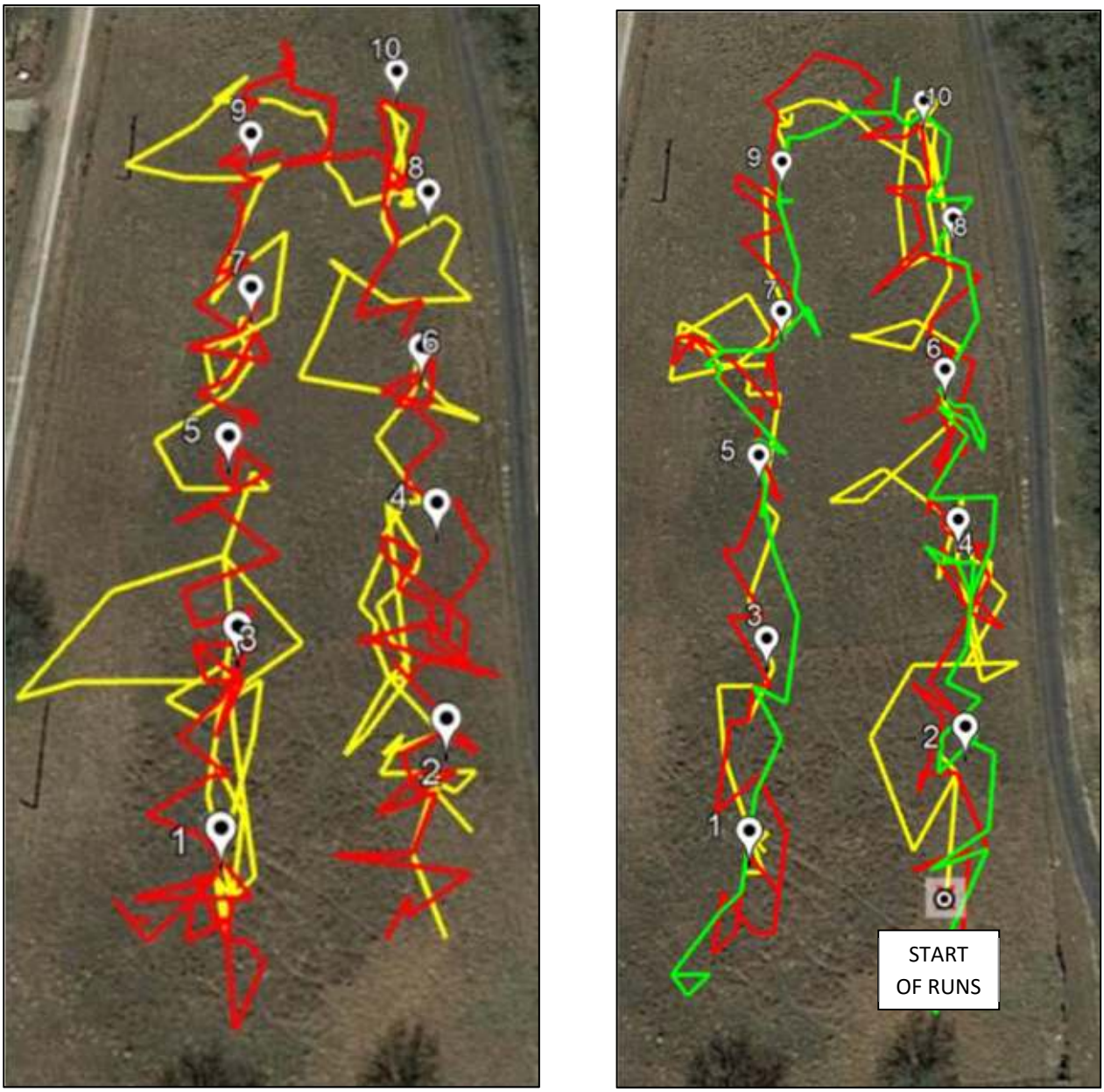

Figure 4.2 Combined WAS GPS track lines for two canines on 11 February (left) and three canines on 12 February (right)

4.2.2 PID Tests

Following the canine runs on each day the PID was walked along the length of the 15-ft (5-m) and 5-ft (1.5-m) pipe arrays as if the location were a pipeline Right-Of-Way (ROW), with the sample port held as close to the ground as practicable; approximately 2 inches (5 cm) from the ground surface. At a slow and steady walking pace the PID did not detect any VOCs from any of the target pipes, except for a spike (2.5 ppm) while walking over the Juniper crude 15 ft (5 m) pipe. For the other targets, the PID only detected VOCs if the sample port was held still for several seconds inside the target pipes and very close (<1 inch or <2 cm) to the soil surface. Under these circumstances, other than the Juniper target, VOCs were detected on four (4) of the seven (7) oil targets in the range of 0.2 to 0.5 ppm. The non-detects were at both occasions on the pipe that contained the tar ball target and on the second run over the dilbit target (Table 4.5). VOCs were detected at each of the four (4) oil targets in the shallower depth 5-ft (1.5-m) array.

Table 4.5 WAS PID Readings (15-foot - 5 m and 5-foot - 1.5m Targets)

OIL TARGET	Date	Approx. Time	Oil Target Depth (ft / m)	PID Reading (ppm VOC)
empty pipe	2/11/2020	10:30	5 / 1.5	0.0
blank - soil	2/11/2020	10:30	5 / 1.5	0.0
Bunker C	2/11/2020	10:30	5 / 1.5	0.6
Bunker C	2/12/2020	13:20	5 / 1.5	1.3
Juniper	2/12/2020	13:20	5 / 1.5	0.2
CTC	2/12/2020	13:20	5 / 1.5	0.6
empty pipe	2/12/2020	10:15	15 / 5	0.0
blank - soil	2/12/2020	10:15	15 / 5	0.0
tar ball	2/11/2020	10:00	15 / 5	0.0
tar ball	2/12/2020	10:15	15 / 5	0.0
Bunker C	2/11/2020	10:00	15 / 5	0.3
Bunker C	2/12/2020	10:15	15 / 5	0.5
dilbit	2/11/2020	10:00	15 / 5	0.2
dilbit	2/12/2020	10:15	15 / 5	0.0
Juniper	2/12/2020	10:15	15 / 5	2.5
CTC	2/12/2020	10:15	15 / 5	2.0

5 Discussion and Conclusions

The 2020 API field trials sought to answer two questions:

- Can a canine detect weathered and "heavy" oils?
- Can a canine be used to detect oils to greater depths than previously tested (36" - 90 cm)?

The indoor carousel tests, replicated using three different canines, provided conclusive evidence that canines can detect heavy (Bunker C) and very weathered (Macondo "Juniper" and tar ball) oils when following double-blind test protocols.

The Wide Area Search (WAS) open field tests, replicated using three different canines, provided evidence to confirm that heavy and very weathered oil can be detected at depths to 15 ft (5 m) in soils when following double-blind test protocols.

5.1 General Observations

The API project manager and other technical visitors attended the second day of the trials to observe the carousel and Wide Area Search field tests. The decision to shorten the planned delineation tests on the shallower depth targets in the "certification array" (Sections 3.2.2 and 4.2) was taken in consultation with this group.

All three canines responded correctly and quickly on target oils. Nika and Lily had considerable prior experience on weathered oil and had no issues locating all targets very quickly without any confusion. The less experienced young English Springer Spaniel, Poppy, showed some hesitations during her first runs on the indoor carousel tests but was successful on all of the five oil types on her three (3) runs during the WAS field tests; so presumably she had learned to recognize all of the oil types from the indoor tests.

Poppy had some initial issues in the carousel tests understanding that the Juniper oil was the target as this was her first exposure to a heavily weathered type of oil. This situation had been explained to the observers prior to working with Poppy and the behavior that she displayed was typical and anticipated. Poppy first conducted a search of the entire carousel and then began to sit at various places waiting for feedback on whether she was correct or not. On the third session of being "marked" for responding on the new target she then responded correctly with no "false" alerts.

Marking is a system utilized in the training of canines based on positive reinforcement. A "mark" is a bridge between a correct behavior and a reward and therefore is an instantaneous communication between the handler and the canine that the intended criteria have been achieved. During the trials both verbal (handler saying "yes") and mechanical markers were used: a mechanical marker is a small (2" x 1") plastic box with a metal bar which makes a "click" sound when depressed by the handler. In a normal training cycle a new target odor would be introduced in a less distracting environment and with a simple "search, sniff, mark" sequence three times, which would avoid any confusion from the canine.

In this scenario the canine was asked to search eleven (11) distraction pots (sand) and one pot with new, un-imprinted target, hence her initial confusion. These results suggests that canines should be "marked" with the appropriate target prior to conducting field surveys

Breed differences in work ethic were demonstrated throughout the trials. Labradors are innately calm dogs which were bred to maintain a quiet and calm disposition either on the shooting line or in a duck blind. They are methodical in their hunt behavior and often are directed at distance to retrieve a bird. English Springer Spaniels were bred to hunt in thick vegetation and flush birds in hiding and then retrieve them with minimal guidance from the hunter. This translates into the detection field as a Labrador's behavior tends to be calmer in search style than a Spaniel. However, each breed has the same detection capabilities despite their differences in search approach. The Spaniel, Poppy, was selected as an Oil Detection Canine in response to restrictions recently imposed on the travel of larger dogs by airlines. A Spaniel weighs half that of a Labrador which can be an advantage for field deployments as there are fewer travel restrictions and smaller transport kennel size requirements for this smaller and lighter breed.

5.2 Carousel Tests

All three canines responded correctly and quickly on the target oils.

The indoor carousel tests were designed to assess the ability of trained canines to detect heavy and weathered oils. The tests were successful in this respect as all 38 targets were quickly identified. The experienced canines correctly detected all of the targets that were presented to them with no "false positives". The tests presented an opportunity to assess a new English Springer Spaniel. She hesitated on a couple of occasions, but nevertheless Poppy's behavior was typical of a detection canine in training and she did detect all of the oil types

The PID did not detect any of the oils in the carousel containers as set up for the canine tests. VOCs only were detected when the perforated lids were removed and the sample probe was inserted directly into the pots and held stationary above the target jar. The PID did not detect the tar ball targets. A better understanding of the components of the oil products that the canines are actually detecting would allow for a closer comparison of the effectiveness of a canine versus a PID. However, these results suggest that canine detection is more sensitive than PIDs in an open-air environment. Bulk oil VOC, semi-volatile organic compound (SVOC), and total petroleum hydrocarbon (TPH) analyses of the study oils are in progress and will provide greater insight into the quantities of chemicals present in the bulk oil samples and the potential thresholds above which canines can detect weathered/heavy oil in the environment.

5.3 Wide Area Search Field Tests

The first day 15 ft (5 m) target depth field trial was completed with Nika and Poppy on three products (dilbit, Bunker C, and tar balls). The crude products (weathered Macondo "CTC" and very weathered

Macondo "Juniper") were not acquired until later that same day and were in place less than 24 hours prior to the second day of field tests, when all three canines were deployed. The success score for the fifty (50) targets inspected by the three canines during the five (5) runs was 98%: one very weathered oil target (the Macondo "Juniper") was not detected.

During the first day the two canines involved were worked with the wind toward them on the first five 15 ft (5 m) pipes (the east side of the array: Figure 3.4 and Attachment B), and both correctly detected the Bunker C and dilbit targets from approximately 100 feet (30 m) downwind and followed the scent pool to source. For the second set of (west side) five pipes, the canines were then worked with the wind on their backs. In this case the final pipe contained tar ball oil and the canines were approximately 6 feet (2 m) from the source before showing a change of behavior. This capability was anticipated due to the more volatile nature of Bunker C and dilbit in comparison to tar ball oil. On that first day, the handler was able to accurately guess which of the three products were in which target, based on the distance that the canines caught the scent of each target.

In comparison, a "search" using the PID close to the ground at a slow and steady walking pace was unable to detect most of the products at either 5 foot or 15 foot depths, except for a spike while walking over the recently-installed Juniper crude 15 foot (5 m) pipe, and only detected other targets if the sample port was held for several seconds inside the target pipes and very close (<1 inch or <2 cm) to the soil surface. Under these circumstances, VOCs were detected on five (5) of the eight (8) oil targets; the non-detects were on the pipe that contained the tar ball target on both occasions and on the second run over the dilbit target. VOCs were detected on each of the four (4) oil targets in the 5-ft (1.5-m) array under the same stationary sampling circumstances.

The Wide Area Search tests were designed to assess the ability of trained canines to detect heavy and weathered oils and at greater depths (15 ft - 5 m) than previously tested (3 ft - 90 cm). Twenty (20) of the twenty-one (21) 15-ft depth oil targets were correctly detected. Two canines detected all 5 oil types, including the most weathered target, the tar ball oil, on all 5 runs over that target. One canine detected 4 of the 5 oils, not locating the very weathered semi-solid Macondo "Juniper" oil during the one run over that target oil. Both canines used for the 5-ft (1.5 m) tests detected all 3 targets.

The subsurface oil search rates logged for the three canines in these trials translate to an average working speed for a 150-foot (45-m) wide, flat grassy terrain, ROW corridor on the order of five (5) miles of 100% coverage in one hour or less, or approximately twelve (12) miles in an hour for a 60 foot (20-m) wide ROW. This rate is considerably faster than a normal walking speed or an All-Terrain Vehicle (ATV) visual search speed for surface oil that would require a zigzag search track similar to that of a canine. Past field spill deployments in similar and rougher terrain conditions (Owens and Reimer 2018) have shown that a canine can sustain this search rate for 4 to 6 hours at a time, with suitable rest periods, for 5 to 6 days in a row.

6 Acknowledgements

Frank Schembre of Spectrum Canine Solutions loaded and constructed the first set of three oil targets and blank native soil targets in the 15-foot pipes. Technical field support during the trials was provided by Helen Dubach (CTEH) who directed the tests and ensured that the protocols were followed, Elliott Taylor (Polaris Applied Sciences) who logged the tests and assisted with loading the second set of two oil targets, and Alison Craig (Polaris Applied Sciences) who videotaped the tests.

The Global Training Academy of Somerset, TX, provided the fields for the placement of the pipe arrays.

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Attachment A: PID Calibration Log

CTEH
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Air Monitor Calibration Log

Date MM/DD/YYYY	Time HH:MM (military)	Instrument	Serial Number	Cal Gas	Concentration	Lot Numbers	Exp. Dates MM/YYYY	Calibrated by F. Last
02/10/2020	10:10	Ultra RAE 3000+	596-912559 15249	Benzene	5 ppm	228051	05/2022	M. Dubach
02/10/2020	11:25	"	"	"	"	"	"	M. Dubach
02/10/2020	12:04	"	"	"	"	"	"	M. Dubach
02/10/2020	14:26	"	"	"	"	"	"	M. Dubach
02/11/2020	10:27	"	"	"	"	"	"	M. Dubach
02/12/2020	10:02	"	"	"	"	"	"	M. Dubach
02/12/2020	12:01	"	"	"	"	"	"	M. Dubach
02/12/2020	13:14	"	"	"	"	"	"	M. Dubach

Project #: 112539 Client Name: OCC-Api Canine trials City, State: San Antonio, TX

Attachment B: 15-ft (5-m) Depth Target Locations Map

The map was developed by the third party that installed the inner pipes with the Bunker C, dilbit and tar ball targets and the four blank targets prior to the trials. The map was sealed in an envelope so that on the first day of the trials no-one on site was aware of the target locations except the field technician who was provided with the envelope/map. The Juniper and CTC weathered oil target pipes were added by the study team following the field trials on the first day (Figures 3.5 and 3.6) after the envelope was opened. Pipes # 2, 3, 8 and 9 were loaded with the native soil but no oil target ("blank targets") and pipe # 5 was empty. (Note: The orientation of this map has south at the top and north at the bottom, the opposite to Figures 3.3 and 3.4).

Attachment C: Field Trials Forms

The following documentation forms were developed specifically for this study:

- Carousel Arm Contents
- Carousel Score Sheet
- Field Trial Survey Forms:
    - 15 ft (5 m) pipe array
    - 5 ft (1.5 m) pipe array
    - 2 and 3 ft (0.6 and 1 m) pipe array
    - 1 ft (0.3 m) pipe array

DATE OF TEST:

Carousel Arm #	Carousel Arm Contents									
	Product/Run #									
	A (Bunker C)	B (Weathered tarball)	C (Dilbit)	D (wx Juniper crude)	E (weathered CTC)					
	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:	TIME LOADED:
1										
2										
3										
4										
5										
6										
7										
8										
9										
10										
11										
12										

Carousel Setup Instructions :

1. Note the test date at the top of the form
2. Place one target pot on a random arm on the carousel
3. Take special care to avoid cross-contamination of target or distractor odors
4. Record the product and arm number in the table
5. Note the time the product was loaded onto the carousel
6. Place non-target/distractors on the other 11 arms, note the contents of each arm by number
7. Use simple descriptions of contents, i.e. target, clean sand, distractor (describe), empty, etc.
8. Note any spillage or other potential for odor contamination

DATE OF TEST:

Product			Test Run Number														
			Canine 1					Canine 2					Canine 3				
			1a	1b	1c	1d	1e	2a	2b	2c	2d	2e	3a	3b	3c	3d	3e
A	Bunker C	TIME ON ALERT/TYPE FALSE ALERT/ARM# TIME OFF															
B	Weathered tarball	TIME ON ALERT/TYPE FALSE ALERT/ARM# TIME OFF															
C	Dilbit	TIME ON ALERT/TYPE FALSE ALERT/ARM# TIME OFF															
D	Weathered crude (Juniper)	TIME ON ALERT/TYPE FALSE ALERT/ARM# TIME OFF															
E	Weathered crude (CTC)	TIME ON ALERT/TYPE FALSE ALERT/ARM# TIME OFF															

LEGEND				
	✓	Alert on oil target	S	Alert: canine sits
	X	Missed oil target	L	Alert: canine lays down
	O	False alert	B	Alert: canine "buzzes"

Scoresheet instructions :

1. Record the start time of each test run

2. Record the result for each run on the scoresheet (alert vs missed target)

3. Record any false alerts on non-target orms; note the pot number(s) alerted on

4. Note the type of alert(s), i.e. sit, lay down, buzz, etc

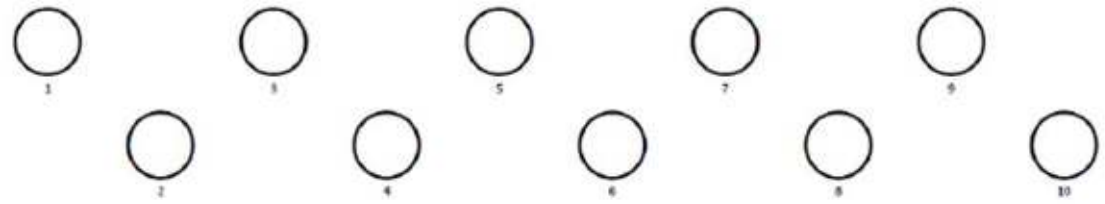
CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: 15ft Odor Detection

1.GENERAL INFORMATION					
Date: (dd/mm/yyyy)		Weather:	Sun / Clouds / Fog / Rain (circle)	Air Temp:	°F
Time Start: (24hr EST)		Humidity:	____%	Wind Direction:	
Time End: (24hr(EST)		Pressure:	____ mb rising / falling (circle)	Wind Speed:	mph

2. DOG TEAM			
Team Number:		Handler Name:	
Canine Name:		Tracking Collar #:	

3. TARGET LAYOUT

Layout Design:



Note in the above sketch:

✓ = Alert on oil target
× = Missed targets
☒ = False alerts on non-oil targets.

Note the type of each alert:

S = canine sits down
L = canine lays down
B = canine "buzzes"

5. COMMENTS

Photographs? Yes / No Numbers: (-)	Video? Yes/ No Video Time: (-)
Completed by:	

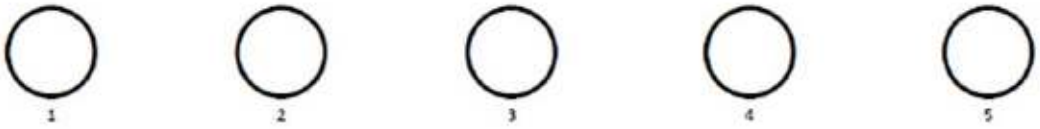
CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: 5ft Odor Detection

1.GENERAL INFORMATION					
Date: (dd/mm/yyyy)		**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	°F
Time Start: (24hr EST)		**Humidity:**	____ %	**Wind Direction:**	
Time End: (24hr(EST)		**Pressure:**	____ mb rising / falling (circle)	**Wind Speed:**	mph

2. DOG TEAM			
Team Number:		**Handler Name:**	
Canine Name:		**Tracking Collar #:**	

3. TARGET LAYOUT (note green = 3ft, all others are 2ft deep)

Layout Design: (A, B, C...)



4. TARGET DESCRIPTION

Target #	Product/ Material	Oiling Depth (cm-cm)	Oil Volume	Notes
1				
2				
3				
4				
5				

5. COMMENTS

Note in the above sketch:

✓ = Alert on oil target

× = Missed targets

☒ = False alerts on non-oil targets.

Note the type of each alert:

S = canine sits down

L = canine lays down

B = canine "buzzes"

Photographs? Yes / No Numbers: (-)	**Video?** Yes/ No Video Time: (-)
Completed by:	

CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: 2 and 3ft Odor Detection

1.GENERAL INFORMATION

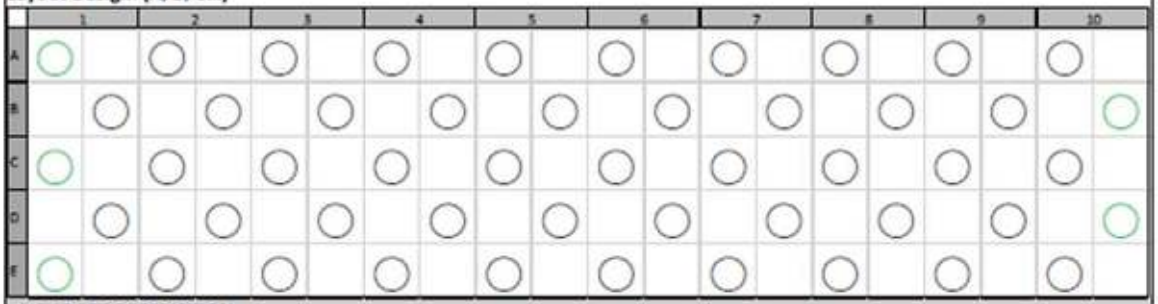
Date: (dd/mm/yyyy)		**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	°F
Time Start: (24hr EST)		**Humidity:**	____%	**Wind Direction:**	
Time End: (24hr(EST)		**Pressure:**	____ mb rising / falling (circle)	**Wind Speed:**	mph

2. DOG TEAM

Team Number:		**Handler Name:**	
Canine Name:		**Tracking Collar #:**	

3. TARGET LAYOUT (note green = 3ft, all others are 2ft deep)

Layout Design: (A, B, C...)



4. TARGET DESCRIPTION

Target #	Product/ Material	Oiling Depth (cm-cm)	Oil Volume	Notes	Target #	Product/ Material	Oiling Depth (cm-cm)	Oil Volume	Notes
A1					C6				
A2					C7				
A3					C8				
A4					C9				
A5					C10				
A6					D1				
A7					D2				
A8					D3				
A9					D4				
A10					D5				
B1					D6				
B2					D7				
B3					D8				
B4					D9				
B5					D10				
B6					E1				
B7					E2				
B8					E3				
B9					E4				
B10					E5				
C1					E6				
C2					E7				
3					E8				
C4					E9				
C5					E10				

5. COMMENTS

Note in the above sketch:

✓ = Alert on oil target

× = Missed targets

☒ = False alerts on non-oil targets.

Note the type of each alert:

S = canine sits down

L = canine lays down

B = canine "buzzes"

Photographs? Yes / No Numbers: (-)	**Video?** Yes/ No Video Time: (-)
Completed by:	

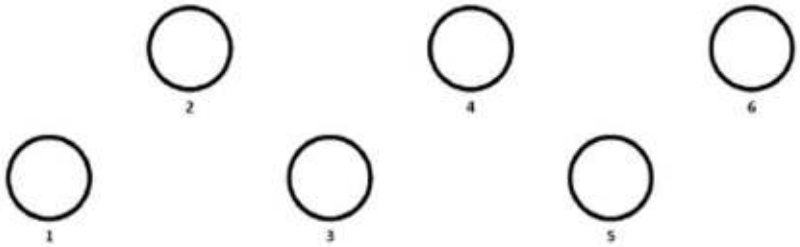
CANINE OIL DETECTION FIELD TRIAL SURVEY FORM: 1ft Odor Detection

1.GENERAL INFORMATION					
Date: (dd/mm/yyyy)		**Weather:**	Sun / Clouds / Fog / Rain (circle)	**Air Temp:**	°F
Time Start: (24hr EST)		**Humidity:**	____%	**Wind Direction:**	
Time End: (24hr(EST)		**Pressure:**	____ mb rising / falling (circle)	**Wind Speed:**	mph

2. DOG TEAM			
Team Number:		**Handler Name:**	
Canine Name:		**Tracking Collar #:**	

3. TARGET LAYOUT (note green = 3ft, all others are 2ft deep)

Layout Design: (A, B, C…) _____



4. TARGET DESCRIPTION

Target #	Product/ Material	Oiling Depth (cm-cm)	Oil Volume	Notes
1				
2				
3				
4				
5				
6				

5. COMMENTS

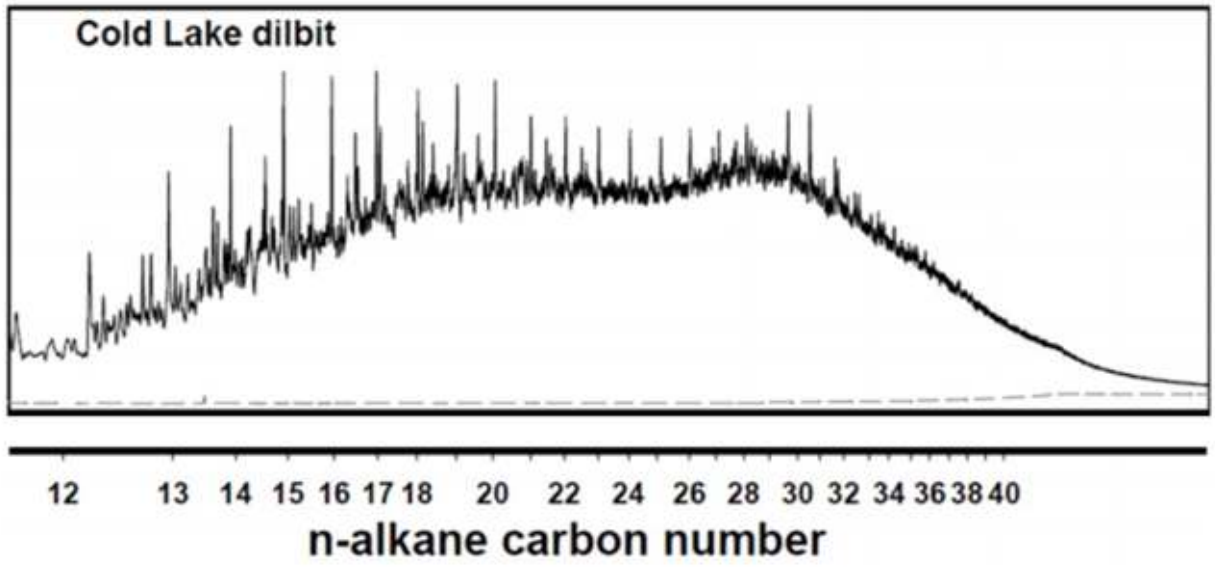
Note in the above sketch:
✓ = Alert on oil target
× = Missed targets
☒ = False alerts on non-oil targets.

Note the type of each alert:
S = canine sits down
L = canine lays down
B = canine "buzzes"

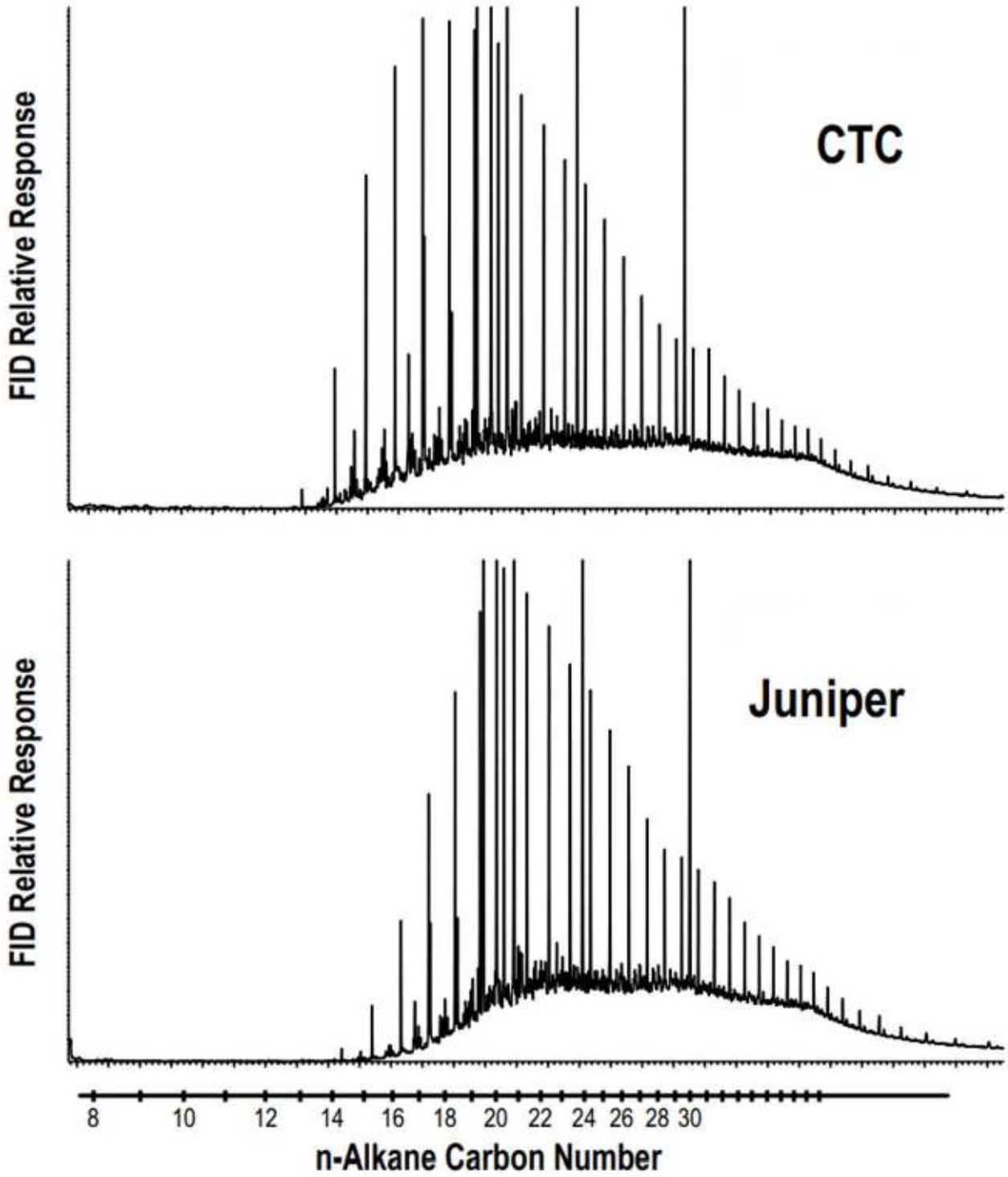
Photographs? Yes / No Numbers: (-)	**Video?** Yes/ No Video Time: (-)
Completed by:	

Attachment D: Target Oils Chromatography

Representative Cold Lake Blend diluted bitumen (from Swarthout *et al*. Figure 2.2 in NAS 2016)



Representative weathered Macondo Crudes: “CTC” at 3 days after the spill and “Juniper” at 5 days post spill (from Cook *et al*. 2020 and NOAA 2015)



Target Bunker C and tar ball oil. Aliphatic Hydrocarbon/Total Petroleum Hydrocarbon Chromatograms (from B&B 2020)